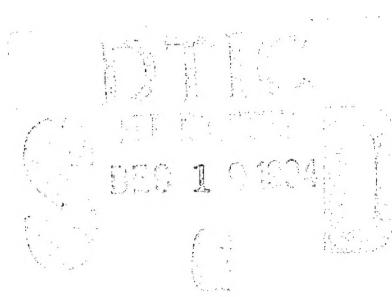# NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

APPLYING MULTIMEDIA TO THE MK 92 MOD 2 MAINTENANCE ADVISOR EXPERT SYSTEM
by
Paul J. Meisch
September, 1994
Principal Advisor: Martin J. McCaffrey

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13. ABSTRACT *(maximum 200 words)*

This thesis is part of a software project to develop a diagnostic expert system for the MK 92 Mod 2 fire control system (FCS) daily system operability test (DSOT). The focus of this work examines the feasibility of applying multimedia, in the form of graphics, digital video, sound, and CD-ROM technology, to the MK 92 Mod 2 Maintenance Advisor Expert System (MAES). The MAES application is intended for distribution to fleet sailors in order to increase readiness of the MK 92 Mod 2 FCS and decrease the need for outside technical assistance.

The MAES application is intended for distribution to the fleet on portable computers. In its current form, the MAES includes only text-based procedures and instructions to aid the user. This study examines whether it is technically feasible to employ high-resolution images, digital video, and sound to enhance the MAES and add impact to the current text outputs. Additionally, it explores the costs associated with each media. Given that the MAES will operate on a portable computer, the study also examines the limitations a portable environment places on multimedia technologies. Finally, this study recommends specific instances of incorporating multimedia in future implementations of the MAES.

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**Applying Multimedia to the MK 92 Mod 2
Maintenance Advisor Expert System**

by

Paul Joseph Meisch
Lieutenant , United States Navy
B.S., United States Naval Academy, 1987

Submitted in partial fulfillment of the requirements for the degree of

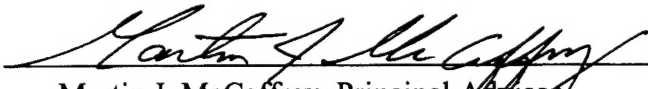MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

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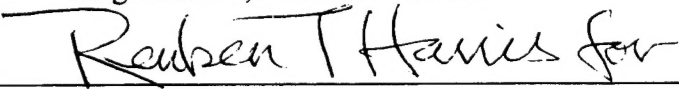NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

This thesis is part of a software project to develop a diagnostic expert system for the MK 92 Mod 2 fire control system (FCS) daily system operability test (DSOT). The focus of this work examines the feasibility of applying multimedia, in the form of graphics, digital video, sound, and CD-ROM technology, to the MK 92 Mod 2 Maintenance Advisor Expert System (MAES). The MAES application is intended for distribution to fleet sailors in order to increase readiness of the MK 92 Mod 2 FCS and decrease the need for outside technical assistance.

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iii

TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

The focus of this thesis is on the enhancement aspects of an expert system development project, the MK 92 Mod 2 Fire Control System (FCS) Maintenance Advisor Expert System (MAES). It is built using a procedural expert system shell for the Microsoft Windows environment and intended for operation on portable, IBM-compatible personal computers. The MAES will be distributed to selected U.S. naval fleet units of the Oliver Hazard Perry Class frigate (FFG).

This thesis explores the feasibility of incorporating multimedia in the MAES. Multimedia is one of the fastest growing trends in computing today [Ref. 1:p. 23]. Full-motion video, high-resolution graphics, sound, and compact disc read-only memory (CD-ROM) technology are appearing in business, educational and entertainment software applications to add impact to and foster interest in using a product.

It has been said that "If a picture is worth a thousand words, then a 10-second video clip, with 150 to 300 images, is a complete novel" [Ref. 2:p. 1]. If this is the case, exploring the feasibility of using multimedia such as instructional video clips, diagrams, photos, and sound in the MAES to aid the enlisted Fire Control Technician (FC) in maintaining and repairing the MK 92 Mod 2 FCS, is worth examining.

1

B. OBJECTIVES

This thesis will provide background of current computer industry multimedia standards and technology for IBM-compatible computers, including high resolution digital images, digital video, sound, and CD-ROM. Secondly, the feasibility of including the previously mentioned multimedia in future versions of the MK 92 Mod 2 MAES will be examined. The research will conclude by examining the limitations of implementing multimedia in a portable, IBM-compatible laptop or notebook computer.

C. RESEARCH QUESTIONS

The primary research question is: *What is the technical feasibility of incorporating multimedia, including high resolution images, digital video, sound, and CD-ROM technology in the MK 92 Mod 2 Fire Control System Maintenance Advisor Expert System?* The following secondary research questions will also be pursued:

(1) What are the costs of including multimedia in the MK 92 Mod 2 MAES?

(2) What limitations does a portable computer environment place on including multimedia in the MK 92 MAES?

D. SCOPE

This thesis examines the feasibility of incorporating multimedia in the MK 92 Mod 2 MAES, developed using the Microsoft Windows based Adept Visual Expert System Builder (hereafter referred to as Adept) by SoftSell (formerly Symbologic Corporation) for use on an IBM-compatible portable personal computer (PC).   Since current multimedia standards cover desktop personal computers, applying multimedia (especially

digital video) to a portable computing environment will be breaking new ground. Additionally, the impact of rapidly evolving technology, as well as fluctuating hardware and software costs, will be addressed. This research will identify instances where the use of multimedia technology in portable computing diverges from the current industry-defined multimedia standards.

E. METHODOLOGY

The initial phase of this thesis was an in-depth literature review which explored the concept of multimedia for PCs from its conception to current day. This included a thorough understanding of available and future multimedia technology, as well as the multimedia industry specified standards.

In conjunction with the literature review, an extensive review of current multimedia hardware and software for IBM-compatible computers was conducted. This included hands-on product testing and evaluation of numerous digital video-capture packages, digital imaging, sound, storage, and CD-ROM equipment. In addition, numerous industry-sponsored multimedia demonstrations and a seminar on CD-ROM technology and CD-ROM publishing were attended.

Familiarization with the use of the Adept expert system shell and its ability to incorporate multimedia objects, as well as how to best incorporate such media was gained by experimenting with different media objects and building simple demonstrations. An understanding of the maintenance and upkeep requirements for current and future multimedia objects to the MK 92 Mod 2 MAES was acquired.

3

Training videos and digital imagery provided by the Naval Surface Warfare Center (NSWC) in Port Hueneme, California, as well as a visit to the MK 92 Mod 2 Fire Control System training site at NSWC provided multimedia objects and allowed first-hand exposure to the system. With the help of a group of engineers from NSWC, specific instances of where multimedia objects that will add impact to the MK 92 Mod 2 MAES, as well as a rationale for choosing them, were identified. They are included for future consideration for implementation in the MAES.

The initial transfer of small demonstrations to an IBM-compatible laptop computer provided immediate feedback to the limitations of applying multimedia to portable computer platforms. A second literature review, more hands-on product testing, and evaluation of IBM-compatible portable PCs were conducted. As a result, a thorough understanding of portable computing capabilities and limitations was acquired. Finally, a comprehensive set of guidelines to consider when purchasing portable computers for the purpose of employing multimedia was developed.

F.   ORGANIZATION OF THE STUDY

This thesis is comprised of seven chapters, followed by three appendices, which are organized in the following manner:

Chapter II - Defining Multimedia: This chapter provides background and an industry definition of multimedia, including the currently accepted multimedia standards for IBM-compatible computers.

4

Chapter III - Graphics and Multimedia: This chapter contains a discussion on how graphics, including digital photography, illustrations, and diagrams, enhance and add impact to applications. Various graphic formats and their relative sizes are described, as well as the means of acquiring such graphics. An examination of how graphics will be applied and maintained in future versions of the MK 92 Mod 2 MAES is made. This is followed by the limitations of portable computing as they relate to graphics.

Chapter IV - Digital Video: This chapter defines and discusses digital video including hardware, software, shortcomings, and the costs of obtaining video. How digital video could be included in future versions of the MAES, as well as maintenance, and portable computing limitation issues, are also discussed.

Chapter V - Sound: This short chapter defines and discusses sound technology, its limitations, and how it could be incorporated in the MAES. It also discusses maintenance and limitations of using sound with portable PCs.

Chapter VI - CD-ROM: This chapter discusses CD-ROM technology and how it might be applied to the MAES, its benefits, maintenance concerns, and the limitations of employing CD-ROM with portable PCs.

Chapter VII - Summary, Conclusions and Recommendations: This chapter summarizes the thesis, and presents the conclusions and recommendations for incorporating multimedia into the MK 92 Mod 2 Maintenance Advisor Expert System.

Appendix A - Instances of Multimedia for MK 92 Mod 2 Maintenance Advisor Expert System: This appendix consists of a number of instances of multimedia

5

(specifically photos and diagrams) identified by MK 92 Mod 2 engineers from NSWC, Port Hueneme, California. It includes information on what the specific images will include, where they would be placed within the MAES, and the rationale for choosing the images.

Appendix B - Building Multimedia Screens for the MAES: This appendix includes detailed instructions for building screens that include multimedia objects, for future implementations in the MK 92 Mod 2 MAES.

Appendix C - Recommendations for Purchasing Portable Computers for Hosting Multimedia Applications: This appendix provides a comprehensive list of hardware and software recommendations to be considered when purchasing a portable IBM-compatible PC that would be used to deploy multimedia applications for the MAES.

II. DEFINING MULTIMEDIA

A.   OVERVIEW

This chapter provides an overview of multimedia. The first section provides a number of definitions for multimedia. The following section presents examples of how multimedia is being used in real-world computer applications. The next section discusses the actual industry specifications for multimedia, followed by a section that discusses the limitations of the current industry specifications. The last section examines the role of standards and the importance of keeping them up to date.

B.   WHAT IS MULTIMEDIA?

Experts in the field define multimedia as "the incorporation of sound, animation, still images, hypertext, or video used in conjunction with computing technology" [Ref. 1:p. 1]. Other definitions of multimedia include, "simply being able to communicate in more than one way" [Ref. 3:p. 9], or "the combination of time-based media--such as voice, animation, and video--and space-based media--such as text, graphics, and images" [Ref. 4:p. 344].

This thesis narrows the discussion of multimedia by applying it only to IBM-compatible computers running Microsoft Windows-based applications, and more specifically, to the MK 92 Mod 2 FCS MAES. Whatever definition one chooses,

multimedia aims to present electronic data and information in their most usable form [Ref. 4:p. 345].

C.   WHY IS MULTIMEDIA IMPORTANT?

Multimedia is important because it adds impact to applications, often providing information that text alone cannot express. Multimedia used effectively can save the user time and money. It can make working with a computer more enjoyable and intuitive.

Take for instance, an enlisted Fire Control Technician (FC) onboard an FFG using the MAES to diagnose a fault in the calibration portion of the daily systems operability test (DSOT) for the MK 92 Mod 2 combined antenna system (CAS). When confronted with a screen in the MAES that asks whether the 870 MHz signal at the output to UD412/A1A6-U1 is within +5, + or - 1.5 dBm, the technician must measure the power outputs with test equipment. This requires the removal of cables. The FC must know which cables to remove. There is an unclassified diagram of the CAS DSOT test set (UD412) available, but it is located in a classified technical manual. However, the diagram in the classified manual does not show the cables that have to be removed to conduct the power checks.

Incorporating a high resolution digital photo at this point in the MAES, that shows the rear view of the CAS DSOT test set with arrows pointing to the specific cables to be removed, would save the FC time and reduce the chance of making an error. The trouble of finding and lugging a classified technical manual to the work area would be eliminated. In addition, the uncertainty posed by an inadequate tech manual diagram that

8

did not provide the desired information would be reduced. Now consider a ten second video-clip of a technician removing the precise cable and one can envision the benefits. Time and effort are saved and accuracy improved. The potential of conducting the wrong test is virtually eliminated.

The previous discussion described just one example of the improvement multimedia offers. There are other real-world instances where using multimedia has saved time, effort, and money. They include education and curriculum development, industrial and commercial training, on-line help for Microsoft Windows applications, informational kiosks, point-of-sale product showcases, interactive product catalogs, maps and geographic information systems, and home education [Ref. 5:pp. 2-3]. The next section discusses the multimedia hardware standards adopted by the computer industry.

D.   WHAT ARE THE MULTIMEDIA STANDARDS?

The first industry standards for multimedia in IBM-compatible computers were established by Microsoft, in conjunction with a group of personal computer manufacturers [Ref. 1:p. 20]. This group eventually formed the Multimedia PC Marketing Council (a subsidiary of the Software Publishers Association), and announced their first standards in mid-1991 [Ref. 5:p. 30]. The original standards, known as MPC Specification 1.0 (abbreviated to MPC), were updated to MPC Specification 2.0 (MPC2) on May 17, 1993 [Ref. 6:p. 1]. The MPC2 standards specify minimum hardware requirements for multimedia PCs including CPU type, hard-disk drive size, amount of

random access memory (RAM), type of CD-ROM drive, video card, floppy disk drive, joystick, and sound card. The purpose of the MPC standards, depicted in Table 1 [Ref. 3:pp. 15-16], was to ensure that any applications designed and implemented by software developers, using the standard, could be reproduced on a computer meeting the standard's minimums.

TABLE 1. REQUIREMENTS TO MEET MPC AND MPC2 STANDARDS

Component	MPC	MPC2
CPU	16 MHz 386SX	25 MHz 486SX
Hard Disk	30MB	160MB
Random Access Memory (RAM)	2MB	4MB
CD-ROM	Sustained 150 kilobytes-per-second transfer rate; average seek time of one second or less; 10,000 hours mean time between failures (MTBF); recommended 64K of read-ahead buffering; volume knob on the front and audio (music) outputs.	Meets MPC levels but *doublespeed*; offers a sustained 300 kilobytes-per-second transfer rate, using less than 40 percent of processor time; average seek time of 400 milliseconds or less; multisession-capable and extended architecture (XA) ready.
Video Card	VGA display (640 x 480 with 16 colors)	640 x 480 with 16-bit color (65,536 colors)
Floppy Disk	3.5 inch high-density	3.5 inch high-density
Joystick	Yes	Yes
Sound Card	8-bit Digital-to-Analog Converter (DAC) and Analog-to-Digital Converter (ADC); a sample rate of 22.05 and 11.025 kHz; microphone input; internal synthesizer hardware with multi-voice, multi-timbral capabilities and six simultaneous melody notes plus two simultaneous percussive notes.	Meets MPC levels but adds 16-bit DAC and ADC; a sample rate of 44.1, 22.05, and 11.025 kHz; must be stereo.

Rapid advances in PC technology, as well as multimedia hardware and software technology, present a challenge for keeping standards up to date. Unfortunately, a new MPC standard which reflects these advances is absent, and there is no evidence that the MPC Marketing Council plans to revise the standard in the immediate future [Ref. 7:p. 250]. The next section discusses the deficiencies of the MPC2 standard in view of the new technology available since 1993.

E. THE DELAY OF A NEW STANDARD FOR MULTIMEDIA

As previously discussed, a number of improvements in computing technology have evolved since the announcement of MPC2 in May, 1993. The most important advances include: affordable, advanced microprocessors (CPUs), affordable desktop video, faster data-transfer, improved PC bus architectures, and enhanced portable computing. Marked improvements in each of these areas and the impact of the present standard are discussed below.

1. Fast, Affordable CPUs

Since the MPC2 standards were announced, the most significant development in the IBM-compatible PC industry impacting multimedia is the widespread availability of powerful Intel 486 and Pentium CPUs. They offer increased computing power orders of magnitude better than the aging 486SX chip. This is important because many forms of multimedia are scaleable, i.e., the more powerful the host computer's CPU, the better multimedia (such as full-motion digital video) will playback [Ref. 8:p. 1]. For instance, a multimedia computer with an Intel 486DX2 66 megahertz (MHz) processor is capable

11

of playing video at the rate of 30 frames per second (fps) in a 320 x 240 pixel-size window. A 486SX 25 MHz equipped PC can playback less than 15 fps in the same size window [Ref. 9:p. 2]. This is further discussed in Chapter IV.

Figure 1 shows the latest Intel Comparative Microprocessor Performance (iCOMP) index [Ref. 10:p.1].

The iCOMP index is an easy-to-understand rating that reflects the relative performance of different Intel microprocessors. It summarizes eight different performance measures into one simple number. The higher the iCOMP rating, the higher the relative performance of the microprocessor. The iCOMP index is designed to model typical application usage over the next three to five years and therefore includes current 16-bit applications as well as emerging 32-bit applications. The iCOMP index reflects the performance of the microprocessor only, not the performance of an entire system. The index measures microprocessor performance in four areas of processor performance: integer, floating-point, graphics, and video performance [Ref. 10:p. 1].
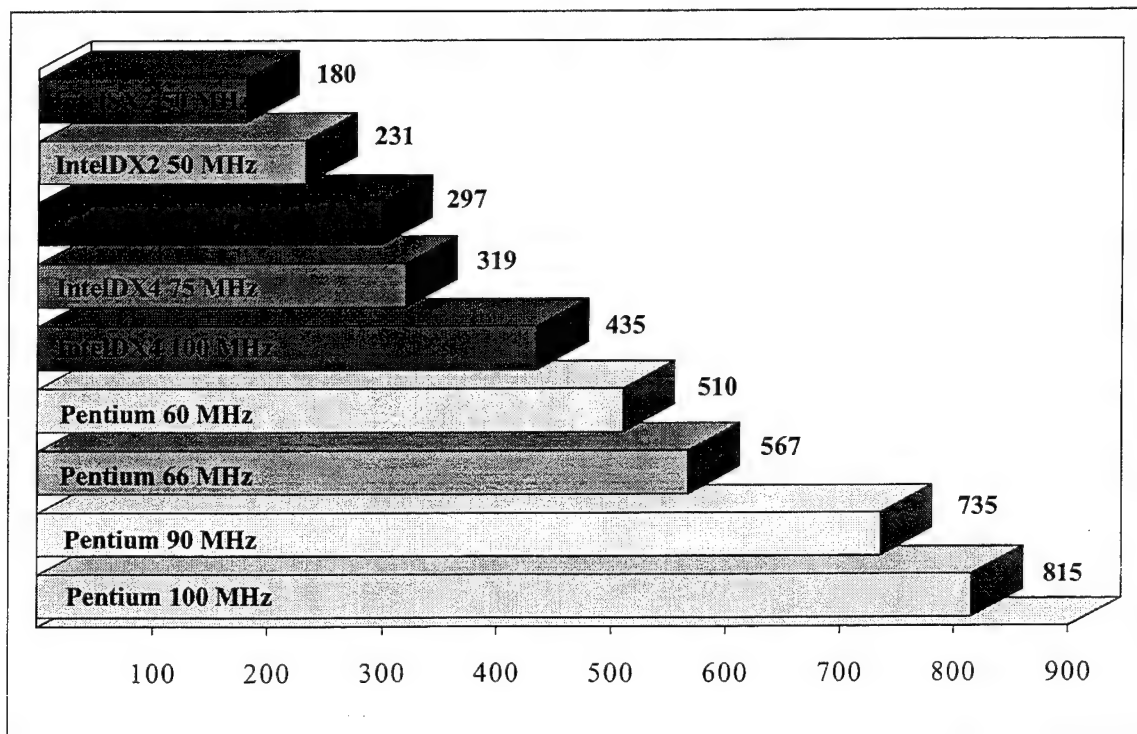
Figure 1. The Intel Comparative Microprocessor Performance
(iCOMP) Index

a. Why use the iCOMP index?

The iCOMP index quickly illustrates performance differences among Intel processors. Also, the iCOMP index chart "clearly demonstrates the price/performance advantage of one Intel processor over another" [Ref. 10:p. 1]. For example, for a relatively small price differential, the Pentium 66 MHz processor with an iCOMP rating of 567 delivers almost twice the processing power of an Intel 486DX2 66 MHz processor [Ref. 10:p. 2]. Even though both processors have the same speed in Megahertz, the Pentium performs nearly twice as well. Notice that the 486SX 25 MHz processor called for in MPC2 standards, as well as the 486DX 33 MHz are not even used in the iCOMP index. Faster, more powerful processors have replaced them as standard issue in today's off-the-shelf PCs.

b. What does megahertz (MHz) measure?

Megahertz is a measurement of the frequency (or clock speed) at which the microprocessor operates. While megahertz is one component of overall processor performance, it is not, by itself, a good measurement. Advanced microprocessors, like the Pentium processor, incorporate many new features and technologies that dramatically impact processor performance.

Megahertz can be compared to revolutions per minute (RPM) in a car's engine. But, when comparing engines, horsepower is a better indicator of performance than RPMs. This is because a small engine might operate at high RPMs but have much less power and performance than a bigger engine. In the same way, faster frequencies do not always translate into faster microprocessors. The iCOMP index, just like the horsepower of an engine, provides a better measure of performance [Ref. 10:p. 3].

13

c. *How affordable is the extra performance?*

The previous sections have described the relative performance improvements in processors, but at what cost to the user? Benefiting from Advanced Micro Devices' (AMD) victory in Intel Corporation's suit over the right to legally manufacture 486-cloned microprocessors, coupled with the introduction of the joint, IBM-Apple developed PowerPC, IBM-compatible CPU prices are decreasing daily. A recent San Jose Mercury News, Sunday Computing section advertisement listed a 486DX2 66 MHz processor at $258 dollars, a Pentium 60 MHz processor at $459 dollars, and a Pentium 90 MHz processor at $728 dollars [Ref. 11:p. 3]. As an example of how drastically prices have fallen, only a year ago the 486DX2 66 MHz processor's retail price was only slightly less than the cost of today's 90 MHz Pentium [Ref. 12:p. 309].

2. Digital Desktop Video

Digital desktop video is a relatively new technology that allows motion picture or television quality video to be captured (recorded) and played back on PCs. Capturing video requires an input source (such as a video camera), an internal video capture board, and compression/editing software. Video playback does not require any special hardware, but needs some sort of playback software.

Specifications for digital desktop video capture and playback are conspicuously absent in MPC2 standards. By May of 1993, numerous affordable desktop video capture and playback packages that included hardware and software were available [Ref. 13:p.

14

32]. Despite this, no standard for desktop digital video, while admittedly an emerging technology, was included in the MPC2 standards.

As a minimum, new standards should specify a capture board that is capable of capturing at least 15 fps in a 320 x 240 pixel size window, at a minimum color depth of 8-bit (256 colors) [Ref. 14:p. 2]. This capture board should also support the use of a number of competing video compression/decompression (codec) schemes. This allows end-users to avoid proprietary codecs as improved technology evolves. Additionally, any future standard should specify a CPU that is capable of supporting capture and playback at minimum fps rates and window sizes. The current CPU specification can barely playback and is incapable of capturing video in all but the smallest on-screen windows [Ref. 14:p. 5].

The Microsoft Windows' *Video for Windows* software package, which uses the Microsoft patented audio-video interleaved (AVI) process, is the *defacto* video-capture and playback software standard, and supports numerous codecs [Ref. 15:p. 1]. As discussed previously, the scalability of digital video, or the ability to provide a better display on machines with faster processors, merits consideration in raising the minimum CPU specifications for MPC when, and if desktop video is included. Chapter IV will examine the details of how CPU speed and video-capture/playback are related.

3. Faster Data-Transfer

Partly in response to the growing trend in digital video for the PC, mass storage device (hard-disk drives and CD-ROM players) performance has been greatly improved

15

[Ref. 16:p. 41]. As the size of a digital video file can easily reach into the 30 megabyte (MB) range, the 160 MB specification for MPC2 hard-disk drives is inadequate and long-overdue for an update.

In order to transfer such large files in and out of memory, faster access times and data-transfer rates are essential. Access time is the average time in milliseconds (ms) required to locate and load a minimum amount of data from the disk to the PCs RAM buffer to run a specific program [Ref. 5:p. 94]. Data-transfer rate refers to the rate, or amount of data in kilobytes per second (kbps), that the disk can supply to the processor [Ref. 3:p.85]. MPC2 does not contain a specification for the hard-disk drive access/data-transfer rates. Research related to this thesis found that hard-disk drive access speeds of 15 milliseconds (ms) or less produced smooth video playback. To arrive at this conclusion, video files ranging from 5 to 30 MB were tested on three disk drives with 16 ms, 15 ms, and 8.5 ms access times. The disk with 16 ms access time failed to maintain the 30 fps rate without dropping (failing to display) a number of video frames.

While CD-ROMs have provided a solution to the storage of the massive size of digital video files, doublespeed CD-ROM drives with 400 ms or less access, and data-transfer rates of 300 kbps barely suffice for smooth video playback [Ref. 3:p. 85]. Today, triple and quadruplespeed CD-ROM drives are available. This speed refers to the data-transfer rates, not the access speed. Since the specification for the first MPC CD-ROM drive was 150 kbps, doublespeed, triplespeed, and quadruplespeed refers to

300 kbps, 450 kbps, and 600 kbps, respectively. The access times on these drives reach as low as the mid-150 ms range.

Reviews of PC trade publications reveals street prices of large, sub-12 ms hard-disk drives going for around forty-five cents per megabyte, and quad-speed CD-ROM drives for under $500 dollars. High-performance components are readily available and affordable to users. The above discussion provides strong evidence that the MPC2 standard is deficient.

4. Improved PC Bus Architectures

Another deficiency in the MPC and MPC2 standards is the exclusion of PC bus specifications. Today there are two competing bus architectures. Since May, 1993, the *Video Electronics Standards Association's* (VESA) Local Bus (VLB), was the *de facto* standard in off-the-shelf PCs [Ref. 5:p. 80]. It offers improved video and data transfer speeds. It was not included in MPC2. Today, VLB is vying with Intel's peripheral component interconnect (PCI) architecture designed for Pentium processors as the defacto standard. Again, when the winner emerges, MPC standards will need updating. Video display cards and disk-drive controllers for VLB or PCI will take advantage of the improved bus transfer rates, but will not be compatible with the Industry Standard Architecture (ISA) bus common at the time of MPC and MPC2 specifications [Ref. 5:pp 466-467].

5. Portable Computing

Today, more and more people are relying on mobile computing [Ref. 17:p. 1]. The capabilities of portable computers has grown tremendously over the past few years. Powerful, low-power-consuming processors like Intel's 486DX4 offer performance comparable to desktop PCs. Additionally, better color displays, longer lasting batteries, and bigger hard-disk drives, all packaged in smaller, light-weight cases proliferate the retail market [Ref. 17:p. 1]. In response, multimedia applications and hardware are finding their way into portable PCs [Ref. 18:p. 241]. CD-ROM drives, sound cards, and local bus video are now being offered in the latest laptops. While there is no progress evident by the MPC Marketing Council on this issue, as prices fall, and hardware shrinks to fit the portable computing environment, a parallel MPC standard for portables is essential.

F. WHY ARE STANDARDS IMPORTANT?

The previous sections in this chapter suggest the need of an updated MPC standard. As discussed earlier, the MPC standard is important to ensure that any applications designed and implemented by software developers, using the standard, could be reproduced on a computer meeting the standard's minimums. The absence of a new standard is significant because without a standard, new technology development is stifled.

End-users are wary of the risk that purchasing new technology poses. If hardware does not comply to a particular standard, it becomes proprietary. This locks that customer into either purchasing expensive upgrades, or abandoning that hardware

altogether when a standard evolves that does not include that type of hardware. The absence of an update to the MPC2 specifications may actually be causing a slowdown in the consumer market for desktop video, and portable PCs. As hundreds of new multimedia hardware technologies appear on the market, buyers will wait to see which technologies emerge as the standard.

Similarly, manufacturers and developers of multimedia hardware and software are at risk of marketing new technologies that do not comply with whatever new standard is eventually adopted. Another danger arises when smaller companies prolong their development efforts to see what standard eventually emerges. The larger companies can afford to take the risk of pursuing the new technologies that may or may not eventually become the standard. If this happens, the larger companies either take a huge lead over the smaller companies, or absorb the loss. Either way, the consumer loses because prices rise to absorb these losses, or the lack of competition keeps prices high.

It appears that the MPC Marketing Council is content to wait for consumers to choose which new technologies are their favorites before declaring a new standard. The other possibility is that the proliferation of rapidly emerging new technologies is holding back a new standard. Afterall, MPC2 standards were barely announced before triplespeed CD-ROM drives and affordable 486DX CPUs became available.

One final reason to explain the absence of a new standard, could be that the MPC Marketing Council is waiting to see what Microsoft's upcoming release of Windows 4.0, due on the shelves in April, 1995, holds in store [Ref. 19:p. 2]. In any case, there is no

evidence that a new MPC standard will be released in the immediate future. In the meantime, perspective multimedia hardware and software end-users should pay close attention to the product reviews in PC trade magazines, and hope for the best.

G. SUMMARY

This chapter presented some definitions of multimedia, examples of its usefulness, and the current standards for IBM-compatible multimedia computers. It also pointed out a few reasons why the MPC standards announced last year are in need of an update. Finally, it presented the magnitude of keeping standards up to date. The next four chapters provide detailed looks at graphics, video, sound, and CD-ROM technologies and how they were considered for incorporation in the MK 92 Mod 2 FCS MAES.

III. GRAPHICS AND MULTIMEDIA

A. OVERVIEW

The old cliché that "a picture is worth a thousand words" is certainly true when it comes to computers. Pictures or images in computer applications provide the most important element of multimedia [Ref. 20:p. 12]. Imagine the improvement readers felt when the first newspaper with pictures was introduced. Computer applications employing only plain-text might drive end-users to wonder why they did not just stick with a book, pad, or pencil. High resolution color or black and white (gray-scale) images in computer applications change all that. Putting graphics in computer applications sometimes serve only to offer "eye-candy" or make programs more attractive to use, but if they accomplish only that, it is enough [Ref. 20:p. 12]. Using graphics in future applications of the MK 92 Mod 2 FCS MAES will enhance the product by not only providing relief from plain-text, but will also add greatly improved functionality to the application. The previous chapter provided a prime example of the role graphics could fulfill in enhancing the MAES.

This chapter discusses imagery in multimedia applications. These images include high resolution color or gray-scale digital photos, illustrations, diagrams, or line-art. The chapter also examines the hardware required to display these images, applicable software formats for displaying the images, and advantages/disadvantages of the different formats.

Additionally, this chapter provides a description of how to acquire and import digital photos for use in computer applications. The chapter concludes with a discussion on how graphics will be implemented in the MK 92 Mod 2 FCS MAES, the cost and maintenance of these graphics, and how portable computing affects graphics.

B.   WHAT DO YOU NEED TO DISPLAY GREAT GRAPHICS?

In order to display the types of graphics mentioned above, the PC must, as a minimum, meet the graphics requirements of the MPC standards described in the last chapter. Conspicuously absent from any multimedia standards to date is a standard for the display monitor. Fortunately, any video display capable of video graphics array (VGA) quality or better, can display adequate color graphics. This research discovered that even monochrome monitors found on portable computers are usually capable of displaying 64 to 256 shades of gray, which allow image display quality comparable to a good black and white photo. The real key to displaying excellent quality graphics and colors to the screen, is the video display card. This section discusses video display cards, the effect they have on colors, and resolutions of images, and their role in producing graphics in portable computers.

1. Video Display Cards

Video display cards are responsible for controlling the color and resolutions projected on the video display screen. Of the different types of display cards available today, the most important are graphics accelerator cards. Accelerator cards are designed specifically to improve performance in Microsoft Windows in the following two ways.

First, they execute many of the graphics calculations that the CPU normally would perform, but at a much faster rate [Ref. 5:p. 464]. Second, they eliminate the bottleneck that stems from sending streams of bytes to your graphics adapter card over the computer's relatively slow input/output (I/O) bus, by using special drivers that intercept instructions from the Windows graphics generator (GUI.EXE) to the CPU, and sends them to the accelerator's processor instead. Since accelerator cards carry their own onboard processor and memory, the data does not have to travel over the computer's I/O bus, but is displayed directly on the screen.

The more memory the accelerator card contains, the more colors and resolutions beyond VGA's 16 colors and 640 x 480 pixel resolution can be displayed. A minimum of 512 kilobytes (kb) of memory is necessary to display 256 colors and resolutions higher than 640 x 480. One megabyte of memory allows 24-bit (16.7 million colors) or "true color" photo-realistic images in resolutions of 640 x 480, and 16-bit color (65,536 colors) in 800 x 600 resolution. Two megabytes of memory on the video card allows for 24-bit color at 800 x 600 resolution and 16-bit color at resolutions up to 1024 x 768. Gray-scale images contain 256 shades of gray (8-bit) by definition. But while 8-bit color is sufficient for clear, crisp images in multimedia applications, professional photographers prefer color depths of 24-bit for their photo-realistic appearance [Ref. 20:p. 12].

The video display drivers provided with Microsoft Windows only work on specific display cards, so third-party accelerator card manufacturers always include Windows software drivers. They are included specifically to optimize their card's

23

performance. The bottom line is that the Windows VGA driver cannot provide the color capability required to display other than clip-art type images or simple diagrams.

2. Color and Resolution Minimums

The different images used in the course of this research included 24-bit color images, 8 bit gray-scale, and line-art diagrams. In every case except for the line-art, other than standard VGA drivers were necessary to properly display the image. Some of the images currently used in the MAES that do work with the standard VGA driver are "dithered" color photos (i.e., the initial MAES start-up screen), such as Figure 2. This
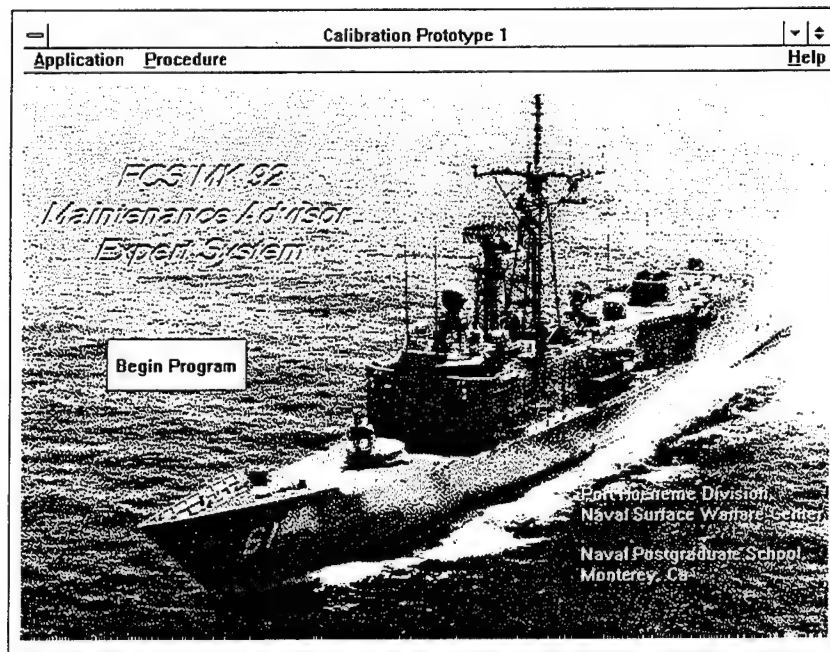
Figure 2. Image quality of "dithered" gray-scale photo

means that the original number of colors have been reduced to a displayable format by spreading out the displayed colors, and inserting white dots. While the essential image is

still recognizable, the resolution is not acceptable to display detailed close-up photos or illustrations.

If a computer has a color display and accelerator card, setting the video mode at 256 colors and 640 x 480 resolution provides more than adequate images. More colors and higher resolutions than that affect the speed at which the application can redraw, and should be avoided unless the accelerator card is of high-end quality (usually over $300 dollars), with a state-of-the-art processor and memory.

3. What about portables?

While most of the affordable portable computers today still have monochrome screens, many of them are capable of producing 256 shades of gray. Testing and evaluation of a number of models of portables revealed that as long as a matching 256 color driver is available for the particular display card (and the card has 512 kb of memory), the monochromes screen displayed crisp shades of gray equivalent to black and white photography.

The higher the cost of the portable, usually means a brighter, sharper picture. However, even a monochrome display capable of only 64 shades of gray produced usable images once the proper driver was obtained. Figure 3 shows a typical gray-scale image and the approximate quality of the display achievable with a 256 color driver on a monochrome screen. Figure 4 exhibits the decrease in quality that results when the same image is displayed with the standard VGA driver on a monochrome display.

25
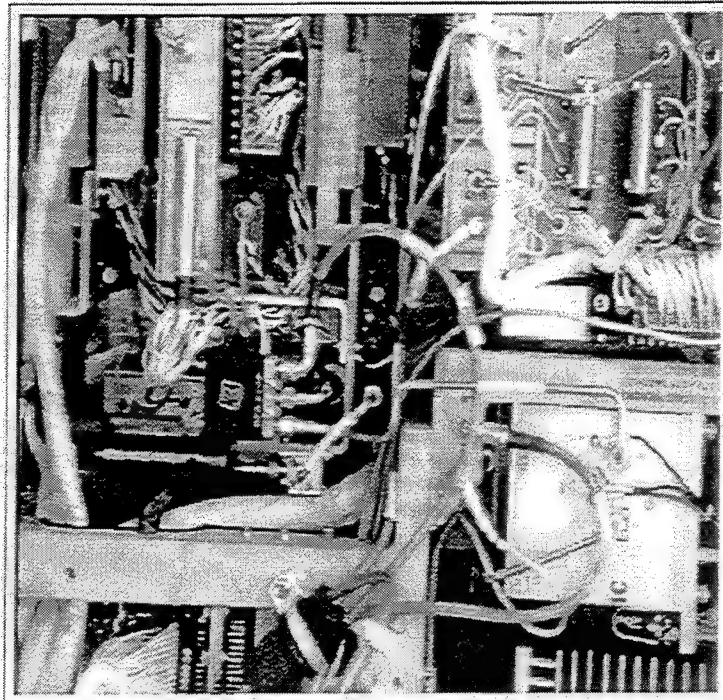
Figure 3. Approximate display quality of 8-bit image
with 256 color driver on monochrome screen
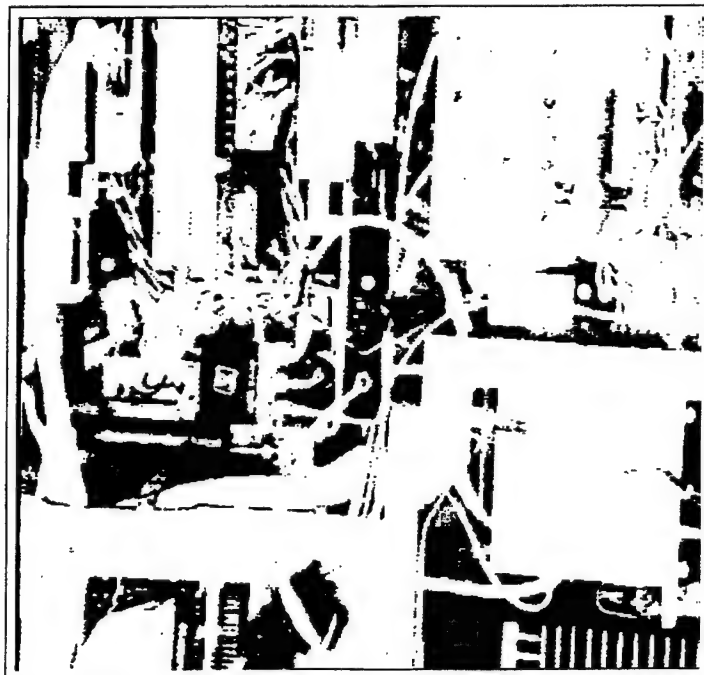
Figure 4. Approximate display quality of 8-bit image
with VGA driver on monochrome screen

Ideally, the best image quality will be obtained with an active-matrix color notebook computer. But even with prices dropping, they are still in the $2,500 price range. Less-expensive, passive-matrix equipped portables do a more than adequate job, and can be found for approximately $1,500, with prices falling rapidly. Even VESA local bus (VLB) video cards appear in portables today, coupling enhanced speed with crisp, colorful displays. The display screen is no longer the weakest link in a portable computer's ability to support high-resolution photos and illustrations. Storage capacity, memory, and battery-life, which are discussed later in this chapter, are of greater concern. The next section offers an explanation of the different types of graphics that Adept supports.

C. ADEPT GRAPHICS FORMATS DEFINED

Adept has the capability to import both bit-mapped and vector-based images. This section examines these two types of image files, as well as the specific file extensions they support.

1. Bit-mapped Images

Bit-mapped images, often referred to as bitmaps, are created when Windows assigns a color and intensity level to each pixel inside the image boundary. Most color bitmaps require one byte per pixel for storage, so large bitmap images create correspondingly large files. Bitmaps are used for images that have shading and lots of realistic detail, such as photos. Bitmaps load faster than vector graphic files, even though they are usually much bigger. Two factors affect image size: resolution and depth. The

greater the resolution (the greater the number of dots in the picture), the larger the image file. By the same token, the greater the depth (number of colors and brightness, i.e. 8-bit), the larger the image file. The size of an image is calculated by multiplying the height (in pixels), by the width (in pixels), and the color depth (in bits), and then dividing by 8. Therefore, a full-size, 640 x 480, 24-bit digital photo will occupy 921,600 bytes of storage space. Figure 5 illustrates the storage size comparison between the different bit-mapped file types for a 24-bit digital photo. Figure 6 shows the dramatic difference in file-size realized when the images are reduced to 8-bit gray-scale format.

The following paragraphs discuss the specific file extensions of the bit-mapped images supported by Adept.

a. BMP

The .bmp extension refers to Microsoft Windows bitmap files in 1-,2-,4-,8-,and 24-bit color depths. These files contain a bitmap header that defines the size of the image, the number of color planes, and the palette used. As illustrated in Figure 5, bitmaps have no size advantage over the other formats. Their only advantage is in the fact that they are the only image file format recognized by Windows without the aid of a third party application.

b. TIF

The .tif extension is short for TIFF (tagged image format file), a format developed by Aldus Corporation. They contain a header similar to the one in .bmp files, and can vary in color depth the same as bitmaps. TIFF files were originally used for the
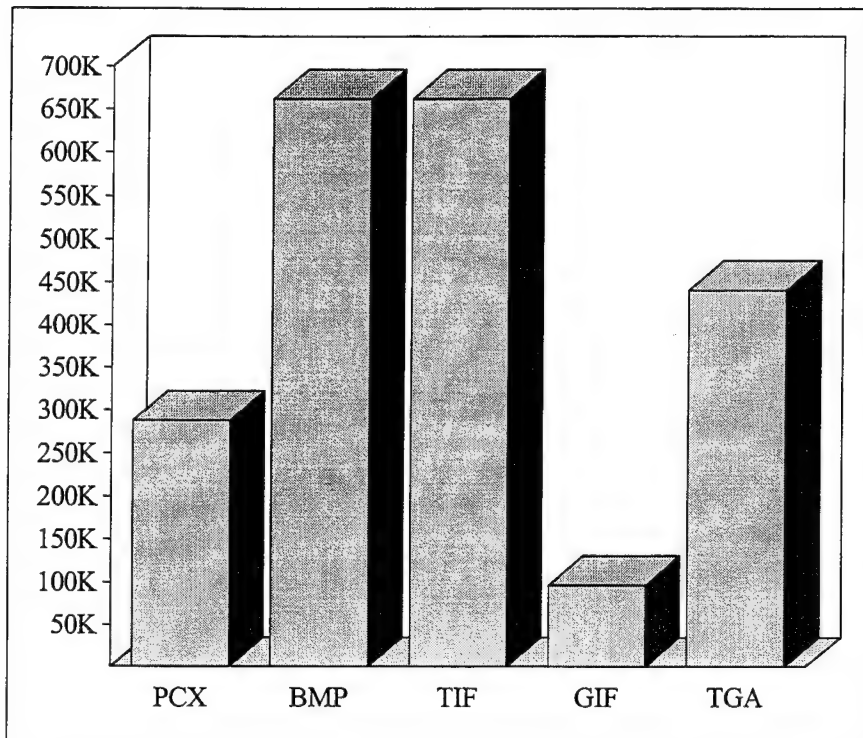
Figure 5. File-Size Comparison of 8 x 5 inch, 24-Bit Graphic, in
Kilobytes
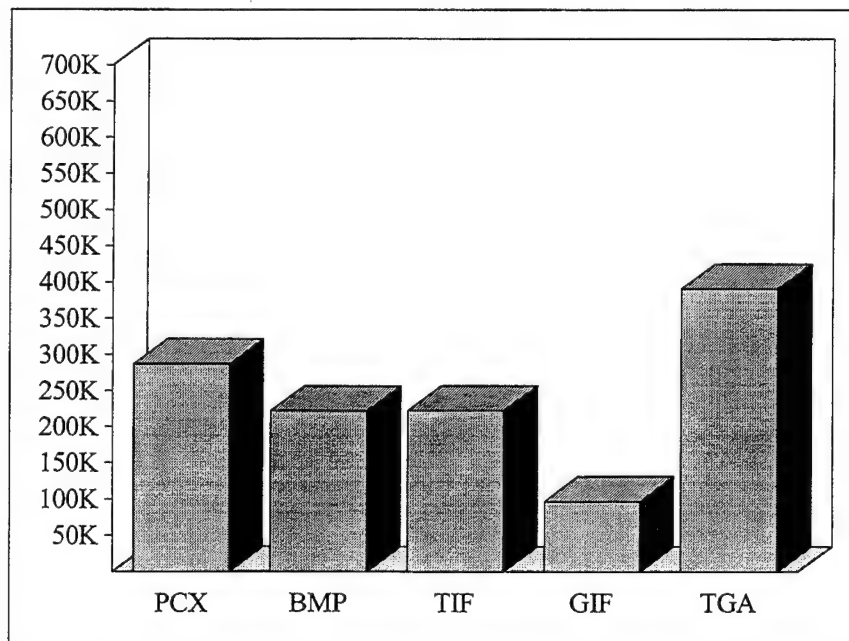
Figure 6. File-Size Comparison of 8 x 5 inch, 8-Bit Gray-scale
Graphic, in Kilobytes

29

most part to store scanned images, but are now a common bit-mapped format to a number of Windows applications. Again, there is no comparative file-size advantage for this file-type.

c. PCX

The .pcx file extension originally comes from files created with Z-Soft Paint applications. Almost every graphics application created in the past five years handles .pcx files. These files are compressed during disk storage, but expand when occupying memory.

d. GIF

The .gif extension originated from the graphics interchange file format, developed to make image transfer on CompuServe quicker. Although these files have a maximum color depth of 8-bit (256 colors), they retain all the clarity and sharpness of the much larger types of bitmaps. By employing their own compression format, .gif files occupy a very small amount of hard-disk space, and then expand when called into memory. As evidenced in Figures 5, and 6, the .gif format provides the best type of graphic file for consideration in Adept applications. This is especially important when considering the smaller hard-disk sizes available for portable computers.

e. TGA

The .tga file comes from the TARGA file format, developed by Truevison for its line of video graphics adapter cards. They were the first to offer relatively high-resolution, high-quality color images for PCs, and were the unchallenged standard

of professional graphic artists for many years [Ref. 5:p. 484]. Now, they are common in many Windows applications. TARGA files contain slight compression, but have no significant file-size advantage over the other formats for color images, and have the largest file-size for gray-scale images.

2. Vector-based Images

Vector-based images, created using drawing applications, are stored as a set of instructions which define the images by their end points, thickness, color, pattern, and curvature of lines and solid objects [Ref. 1:p. 418]. These images are most commonly represented in the form of line-art, clip-art, or diagrams. Vector graphics take up only a fraction of the storage size necessary for bit-mapped files of the same dimensions, so they are an excellent choice for images when they will suffice. The vector-based graphics supported by Adept are discussed below.

a. WMF

This file extension refers to Windows meta file, the standard vector-based file structure of Windows. They can be created by a number of Windows drawing packages. Windows meta files can contain embedded bit-mapped images within the vector-based image, but this adds substantially to overall file-size.

b. EPS

Developed by Adobe Systems, Inc. for compatibility with its PostScript language for printers, .eps (encapsulated PostScript) files are the most popular format for commercial clip-art packages [Ref. 5:p. 485]. Images created in many common Windows

31

drawing programs can be converted to .eps, but their is no clear advantage to using this type of file over the others when considering the MAES.

c. *WPG*

The .wpg file extension is for WordPerfect's clip-art format. Volumes of "ready-made" clip-art of this type are available for use in word-processing applications. This clip-art is primarily theme oriented, with a limited variety of subjects. Clip-art images of this type are not appropriate for use in the MAES, due to their constrictive subject matter.

D. ACQUIRING GRAPHICS FOR USE IN THE MAES

The types of image files described in the previous section can be obtained in many ways. The following paragraphs present the methods evaluated for acquiring potential images for the MAES, and the cost and effort associated with each.

1. Digital Scanners

Digital scanners offer a cost-effective solution for obtaining images. Once the initial investment is made for the hardware and software, there is little additional cost. High-quality flatbed scanners supporting 24-bit (16.7 million) colors are available today for under $1000. Photos or other images are easily scanned in and can then be manipulated and converted to the file formats discussed previously, for incorporating in the MAES. The cost of the professional photographer, if necessary, is the only additional long-term expense for acquiring images in this manner.

2. Digital Photography

Digital photography is another option for acquiring images for the MAES. A relatively new technology, it uses cameras similar to the ones used in conventional photography. Instead of capturing the image to film though, it captures the image digitally, directly to memory contained in the camera. The captured digital image then downloads directly to the computer's hard-disk drive via a cable to the computer's serial port. Then, the image editing begins immediately without any lengthy development process. Portability, and direct camera-to-computer image transfer make this an attractive option. The biggest draw-back to this type of image capture is the expense of the digital camera. High-quality digital cameras, like Kodak's DCS 200 system, offer ultra-high-resolution, scientific quality imaging, but for a price tag of around $10,000 dollars per camera [Ref. 21:p. 2]. There are a couple of less-expensive digital cameras on the market today ($300-$700 price range), but they offer fixed-focus lenses which are not suitable for capturing the close-up details required for potential MAES images. In addition to the cost of the hardware, a professional photographer is still required to guarantee proper lighting, etc., required for quality photos. If technology improves, and prices for digital cameras drop, this method of capturing images for the MAES should be considered.

3. Single Frame Video Capture

Single frame video capture is similar to using digital cameras, in that an image is captured directly to the computer from an external input source such as a video camera,

33

via an internal capture board. Most of the images used for evaluation and testing with the MAES were acquired in this manner. Images of similar quality to the digital camera are obtained for a fraction of the price ($400-$1000 dollars for a quality capture board, plus video camera), but at the expense of portability. All of the capture equipment (including the entire computer and input device) needs to be carried to the location of the particular object. This method of obtaining images for the MAES is acceptable when the subject matter is located in one static location, such as the in the case of the MK 92 test site at Port Hueneme, California. There is still, however, difficulty in obtaining some of the close-up images desired due to the confined quarters, and the size and bulkiness of the capture equipment. This method is by far the most manpower intensive and time consuming due to the setup, the proper lighting considerations, and the sheer unwieldiness of the camera.

4. Building Your Own Graphics

The final method of acquiring graphics for the MAES is achieved by simply building them yourself, using commercial drawing programs. Programs such as Visio, Adobe Illustrator, or CorelDraw offer more than adequate tools to build high-quality schematic diagrams and illustrations. While there is minimal up-front cost (around $100-$500 dollars for the software), there is significant manpower cost in terms of reproducing and ensuring correctness to the graphic.

34

E. APPLYING GRAPHICS TO THE MK 92 MOD 2 MAES

Now that the types of graphics, and the means of obtaining them have been established, the method of implementing them for use in the MAES needs to be considered. Appendix A provides detailed results of a systematic effort by the author, and MK 92 experts from NSWC Port Hueneme, to identify specific areas where graphics could be used in future implementations of the MAES. This includes the rationale for choosing these particular graphics. Appendix B provides instructions for building Adept screens that include graphics. The following paragraphs describe the key points from each Appendix.

1. When would graphics be used in the MAES?

Graphical images should be used in the MAES whenever a photo or illustration can make a procedure of instruction clearer to the technician. These procedures are most often contained in the MAES "How" or "Why" text instructions, or the referrals to the technical manuals. According to the domain experts from NSWC, there are many instances where diagrams or illustrations in the technical manuals are wrong, deficient, or simply non-existent. In other cases, when good graphical aids are available, the technical manuals that contain them are classified and have to be properly protected, preventing easy access. Technicians could save time and effort by placing these images (every case identified by the experts involves unclassified images) into the MAES with specific labeling. The technician would no longer have to refer to the technical manuals, and in most cases, the images placed in the MAES would provide better quality pictures than the

line-diagrams from those manuals. Figures 7, 8, and 9 provide examples of how images could be employed in future implementations of the MAES.

2. How would the graphics be invoked?

Clearly labeled buttons in Adept screens provide the best way to bring graphic images to the user's fingertips. Adept offers a choice of push buttons, radio buttons, or check-box type buttons. These buttons could be programmed to call up a new screen with the appropriate image, and then either return the user to the previous screen, or provide a more detailed chain of images. Figures 7, 8, and 9 show examples of buttons used in conjunction with the MAES. By calling up the pictures or diagrams via a button, the user makes the decision to view the image. Because it takes a few extra seconds to display detailed photos, the user would be spared the need to wait.

3. How would graphics be imported?

Adept has its own facility for importing the types of images discussed previously in the chapter. To import images, the Adept programmer selects a "display" node from anywhere within the Adept application builder mode, and either clicks on the "open display" option, or double-clicks with the mouse on the node itself.

When this is done, a sample display screen appears for programmers to edit to their own individual taste. This includes building buttons, changing colors and screen layout, and importing images. This is done by selecting the "import bitmap" option from the toolbar. After this option is chosen, the programmer can drag the mouse over the screen until the desired frame size for the bitmap is displayed. Next, double-clicking on
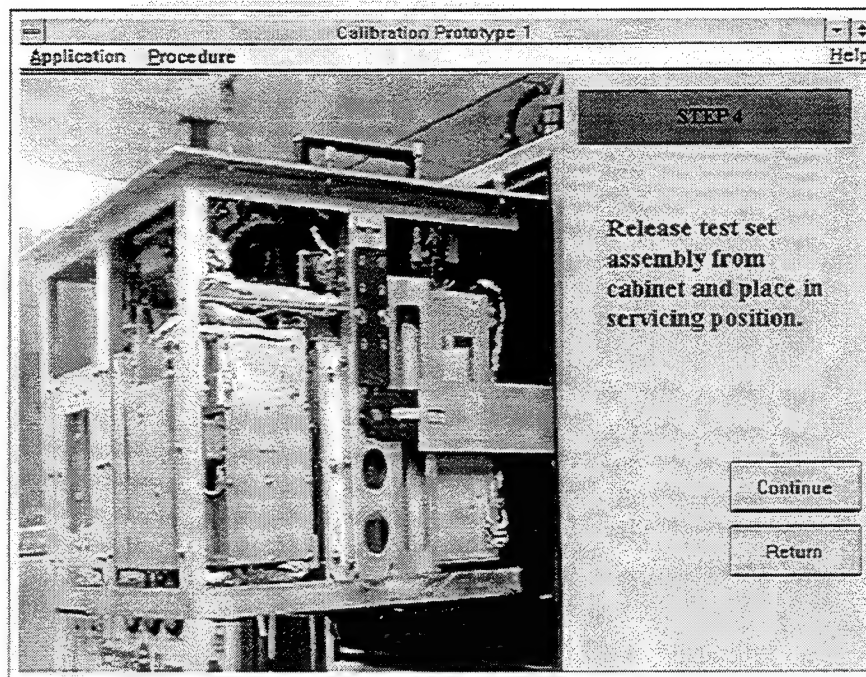
Figure 7. Implementation of Image in MK 92 Mod 2 MAES
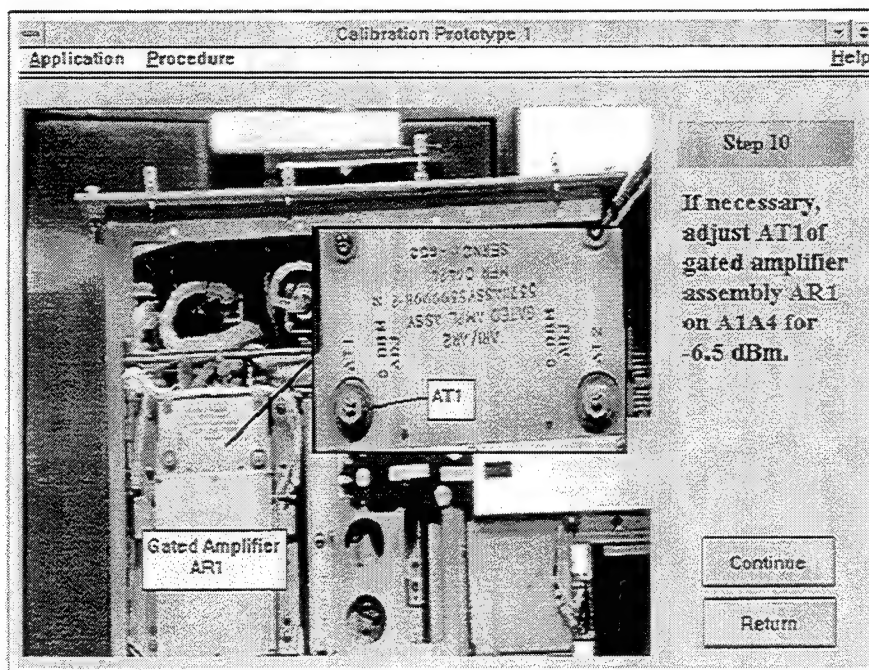
Figure 8. Example of Labeling Image in MK 92 Mod 2 MAES

Figure 9. Example of diagram in MK 92 Mod 2 MAES (some
quality has been lost in importing this graphic)
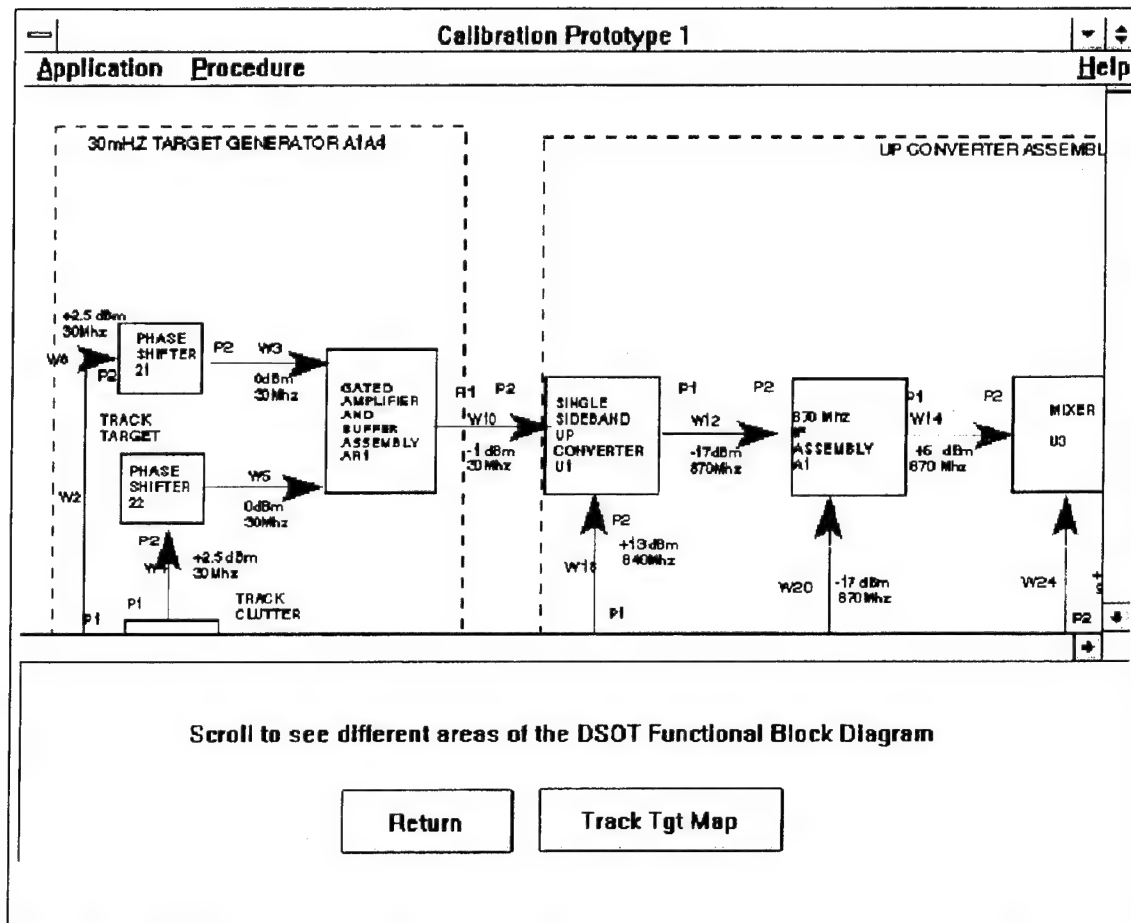
the newly created frame brings up a dialogue box called "Bitmap Properties," which allows a choice of the particular image type and image, from the directory on the hard-disk drive where it is located. Additionally, the user can choose for the image to appear in a regular frame, or can opt for a scrolling frame, if the picture is too large to fit on the screen.

Once the image is in the frame, the user can employ some basic drawing tools, provided by Adept, to make overlaying arrows or labels on the image. While this is a convenient feature, it does not work if the image is placed in a scrolling window as the labels are merely overlaid and not attached to the image. Using a third party image editing program, such as CorelDraw or Adobe Illustrator, is a better way to add labels to the image with very little change in file size.

Since many of the images considered for use in the MAES are common to the same procedures, but located in different diagnostic paths in the MAES, only one instance of the image needs to be physically present on the computer's hard-disk drive (unless different parts are labeled on that particular image). This saves disk space for other programs or more images. Appendix B provides more detailed instructions for building Adept screens that include graphics.

F.   MAINTENANCE OF GRAPHICS FOR THE MK 92 MOD 2 MAES

Over the lifetime of future versions of the MAES that include images, it will undoubtedly become necessary to add new graphics and delete those that no longer apply or have changed. In order to accomplish this inevitability, the MAES project manager

needs a facility to perform this function.   Unfortunately, there is no easy solution for this maintenance.   In order to add new pictures, or delete old ones, a programmer, knowledgeable in Adept, will have to build new Adept screens in accordance with the procedures described in Appendix B.

Fortunately, the MK 92 Mod 2 FCS is a mature system, so whatever images are chosen for inclusion in the MAES will probably not require changing later.   What is likely to happen, though, is personnel from the fleet will request that more images, diagrams, or illustrations be added to clarify procedures and instructions.

One possible way to circumvent this potential problem is to introduce a prototype with a limited number of images to the fleet, and solicit input for places where additional images would be useful. Next, the domain experts from NSWC would evaluate the users inputs, narrow them down, and implement them on a large scale.

G.   LIMITATIONS OF PORTABLE COMPUTING AND GRAPHICS

Earlier in this chapter, it was suggested that the display screen of the host PC for future multimedia versions of the MAES was not the limiting factor. The host portable PC containing a minimum of 8 megabytes (MB) of random access memory (RAM), a large, fast hard-disk drive, and a good battery, is of equal or greater importance.

The importance of having enough RAM cannot be overstated. Microsoft Windows will run with 2 MB of RAM, with 4 MB recommended. But anybody who has had more than minimum exposure to Windows knows that 8 MB is more realistic for adequate performance. When dealing with images, which have to be loaded into memory to be

40

displayed, the more RAM the computer contains, the better. The more RAM a computer contains, the greater the size of the Windows paging file (swap file). Bigger swap files mean better performance in Windows. More RAM, however, means quicker depletion of battery life, but the tradeoff is worth it. Most new portable computers come with only 4 MB of RAM. Since adding extra RAM to portable computers is an expensive undertaking, often requiring a computer technician, sources recommend purchasing 8 MB of RAM with the computer as an original item [Ref. 17:p. 58].

Just as more RAM will boost performance, a large, quick hard-disk drive will provide noticeable improvements in Windows operation. A large hard drive, in the case of a portable intended for multimedia, means greater than 200 MB (Hard-disk drives smaller than 200 MB permit equal performance, but allow for less media files). This allows for the use of a permanent Windows swap file, in addition to the operating system, Windows program, applications, and other data. Permanent swap files are the most efficient type because they occupy a contiguous portion of the physical disk drive, so swapping data occurs more efficiently. The access speed of the hard-disk drive should be no slower than 15 ms. Today, many portable computers ship with hard-disk drives that meet these minimum requirements at reasonable prices.

Finally, a large hard-disk drive will facilitate storing a great number of graphic images. Assuming that the code for the MAES alone occupies no more than 20 MB of disk space, Microsoft DOS and Windows occupy 25 MB, and a permanent swap file occupies 20 MB, that leaves 135 MB of available space for graphics, assuming a 200 MB

41

hard-disk drive. Using the .gif format, at approximately 100,000 bytes per full-size graphic, permits enough disk space for over 1300 images.

The final factor to take into account, when considering using a lot of graphics in a portable computing environment, is battery life. Since bit-mapped images require color and intensity to each pixel, they draw more battery power than regular text and colored backgrounds [Ref. 22:p. 2]. Additionally, the CPU and disk drive have to work harder to process and retrieve large graphics images . Taking these additional loads into consideration, batteries will drain more quickly [Ref. 22:p. 2]. Distributing an extra battery along with the MAES and keeping it charged for standby, ensures maximum up-time for the system.

H.   SUMMARY

This chapter provided a discussion of graphics or digital images, and their role in multimedia applications. It discussed the different types of graphics, and their advantages and disadvantages. Next it examined the different methods of acquiring digital images for use in multimedia applications. Finally, the chapter explored the ways graphics might be included in future implementations of the MK 92 Mod 2 MAES, the cost and maintenance of these graphics, and the impact of using graphics in a portable computing environment. The next chapter provides a detailed examination of digital video, an extension of graphics, and its role in multimedia applications, especially the MAES.

IV. DIGITAL VIDEO

A. OVERVIEW

This chapter defines and discusses digital video[1] including hardware and software requirements. It also addresses the shortcomings/limitations of digital video and the costs of obtaining quality video. Finally, the chapter discusses how digital video might be included in future versions of the MAES, as well as maintenance and portable computing limitation issues.

B. WHAT IS DIGITAL VIDEO?

Digital video is video converted from an analog source, such as a VCR, camcorder, or television, by a special video capture board, so a PC can edit and store it. This video can, but does not necessarily have to, include accompanying sound. Although digital video may seem like a novelty to many computer users, it has enormous potential in presentations, education and training. Just as still images make applications more interesting and add impact beyond the ability of plain text, moving pictures, or digital video, convey a far greater amount of information, as images are presented to the viewer at rates up to 30 times per second.

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[1]The term digital video is often used synonymously in texts with desktop video, and full-motion video, but since digital video is no longer restricted to desktop use, and full-motion video is not an accurate description for all digitally captured video, they do not mean the same thing.

There are tradeoffs, however, to using digital video. Video contains too much information for a PC to process. In its raw form, video in a 320 x 240 pixel-sized window at 30 frames per second (fps) with 24-bit color would take up about 6.6 megabytes per second [Ref. 9:p. 1]. Even the most powerful CPUs cannot process that much information at one time. Part of the solution to this problem is compression, but even with compression, CPUs are pushed to their processing limits, so other compromises have to be made.

As discussed in Chapter II, digital video is a scaleable media. By adjusting the three main factors that determine video quality: the speed of the processor, the video's frame rate in fps, and the size of the video window, suitable video can be captured and displayed. Table 2 demonstrates scalability of video based on frame rate, processor speed, and window size (using Intel's Indeo codec) [Ref. 2:p.2]. For instance, increasing

TABLE 2. DEMONSTRATION OF VIDEO SCALABILITY FOR PLAYBACK BASED ON PROCESSOR, WINDOW SIZE, AND FRAME RATE

Processor	640 x 480	320 x 240	160 x 120
486SX 25 MHz	1 fps	15 fps	30 fps
486DX 66 MHz	10 fps	30 fps	30 fps
Pentium 60 MHz	20 fps	30 fps	30 fps

the processor speed allows an increased frame rate (for less jerkiness) or a bigger video window (for a larger image). Increasing the size of the video window without increasing

44

the processor speed or lowering the frame rate causes frames to be dropped, making the video appear jerky.

Fortunately, even though the standard video frame rate for television in the U.S. is 30 fps (hence the name full-motion video), and the rate for films shown in movie theaters is 24 fps, digital video played at 15 fps is considered acceptable for use in PC applications [Ref. 9: p. 2]. This means that even PCs with slower CPUs can display quality video in a reasonable sized window. Now that the concept of digital video has been defined, the next sections will discuss the hardware and software requirements that enable video capture and playback.

C.   HARDWARE REQUIREMENTS FOR DIGITAL VIDEO

There are two categories of hardware required for digital video: capture hardware and playback hardware.

1. Capture Hardware

Video capture hardware is the physical capture board that fits inside of the computer and, with the aid of software, transforms the analog video data from the external source to digital data for storage and manipulation by the computer. There are many kinds of video capture on the market today. The two most common types are those that capture the video and compress it at the same time, and those that capture video in raw format for compression later [Ref. 1:pp. 170-171].

In the first case, the video is said to be compressed "real-time." These types of capture boards are usually more expensive than the second type because they include an

onboard processor. But the advantage is in avoiding compression after the fact. The second type of board mentioned relies on software compression/decompression schemes (codecs) to compress the raw video after it is already on the PC's hard-disk. This process can take anywhere from a few minutes to over an hour, depending on the size of the video file. Both of these types of capture board use Microsoft Video for Windows (which is discussed later) to control capture settings.

The research for this thesis included testing capture hardware from each of the two categories mentioned above. The first type of board tested was the type requiring compression after the actual video capture. Manufactured by Creative Labs, a leader in the multimedia industry, the "Video Blaster" ($300 dollars) permitted "lossless" compression, a method that allowed files to be decompressed to their original form with no loss of quality. While this board was less costly ($300), other considerations make it unattractive. First, because there is no processor built onto the capture board to aid the computer's CPU in processing the video, the frame capture rate could not compare to the other type of board. The frame capture rate is the number of sustained frames the capture board and CPU can process and save to disk. If the CPU cannot keep up with the number of frames input from the source, frames are "dropped" or omitted, producing jerky video quality. Second, as previously mentioned, compressing raw video after it was captured required up to an hour for a 30 second video clip.

The second capture board tested was Intel's Smart Video Recorder (ISVR)($400 dollars). This capture board has an onboard video processor chip (i750) which interacts

with a unique codec developed by Intel called "Indeo" [Ref. 14:p. 5]. Indeo permits real-time "lossy" compression, which sacrifices a limited amount of quality for much smaller file sizes. Video captured by the ISVR could be edited immediately after capture, and because of the onboard video processing chip, frame capture rate improved sharply over the other product. Fewer frames dropped during video capture produced smoother video playback in the 15 fps range in 320 x 240 sized windows, and 30 fps in a 160 x 120 sized window.

2. Playback Hardware

Once digital video is captured to disk, there is no special type of hardware required for playback *per se*. This is important, because this places no restrictions on applying video to portable PCs. Once again, however, the issue of scalability arises. As discussed previously, the faster the CPU, the smoother the playback rate, and the larger the viewing window. While PCs with 486SX 25 MHz CPUs are capable of maintaining 15 fps playback rates, the viewing window's size measures only 160 x 120 pixels, or one sixteenth of a display screen in 640 x 480 resolution mode. Computers with CPUs of 486DX2 66 MHz or faster permit viewing window sizes of 320 x 240 pixels (quarter-screen sized videos).

Chapter II also discussed the importance of a hard-disk drive with good access speed, and data-transfer rate. The faster the hard-disk drive, the smoother the video appears on the screen. Hard-disk drives with access times slower than 15 ms produce jerky video playback.

47

The video display card also has a role in captured digital video playback. Video accelerators aid the CPU in processing the video to the screen and determine the number of displayable colors. The better the video display card, the better video appears on the screen. Video display cards must supply a minimum of 256 colors to playback usable video [Ref. 13:p. 29].

Another hardware consideration for achieving adequate video playback is RAM. As mentioned earlier, the more RAM a PC contains, the more efficiently data swaps in and out of memory. Additionally, more RAM allows for a larger Windows permanent swap file, and large permanent swap files allow more efficient memory paging. Since large video files require frequent memory paging, large permanent swap files facilitate improved video playback.

There is one special type of hardware that allows video playback at 30 fps, in full-screen viewing windows, the MPEG (Motion Pictures Expert Group) compression format playback board. An MPEG format file contains video that is compressed at rates of up to 30 to 1. These files are captured and compressed only with the aid of expensive hardware ($1000-$5000 dollars) that is not currently affordable to the general public [Ref. 23:p. 2]. Playback requires a special board and software to decompress the video; but since the playback board does all of the work, the 30 fps in full-sized windows can be achieved even with slow CPUs [Ref. 23:p. 2]. This MPEG playback board is available at reasonable prices ($300-$1000 dollars); but the physical size of the board, using current technology, prevents its use in portable PC applications.

48

The reason MPEG is worth mentioning, however, is that several chip-makers predict the release of miniature MPEG compression chips, costing as low as $40 dollars, by 1995 [Ref. 23: p. 2]. These MPEG chips would be able to fit on a PCs motherboard, permitting even portable PCs to be digital video capture and playback capable. If these predictions hold true, a revolution in digital video is on the horizon.

D.   SOFTWARE REQUIREMENTS FOR DIGITAL VIDEO

The three main factors which determine video quality have already been discussed. Three other factors that influence the size and quality of video are the number of colors, the quality of the video sound (if used), and the type of compression. Fortunately, all of these factors are taken care of by Microsoft's Video for Windows (VFW). Video for Windows creates digital video files by storing captured video frames and audio data in alternating locations within the file (interleaving) , and then synchronizing them for playback [Ref. 24:p. 8]. This process, know as "audio visual interleaving (AVI)" is the basis for playing video in VFW and produces files with an .AVI extension. Another key ingredient to using digital video in Windows applications is Microsoft's object linking and embedding (OLE) software. These two key factors to using digital video are discussed in the following sections.

1. Capture, Editing, and Playback with Video for Windows Software

Microsoft's Video for Windows is a collection of programs including: VidCap, VidEdit, and Media Player 2.0. VidCap works with the hardware board (discussed earlier) to capture incoming video frames and store them in AVI format. If the video

49

contains a soundtrack, VidCap also captures and interleaves the audio signals at the same time. VidCap allows the user to choose between a number of codecs, including Intel's Indeo, to determine file size and playback quality. VidCap also allows the user to limit the size of the video file by restricting capture length or limiting the maximum size of the captured video's file.

VidEdit allows the user to edit the captured video sequence on a frame-by-frame basis. By running several instances of VidEdit, a user can combine frames from different video sequences into a single clip. VidEdit is also the means by which raw captured video is compressed "after the fact," if real-time capture hardware is not used. Additionally, it allows the captured video's quality to be improved by manipulating colors, frame rate, and window size.

Media Player 2.0 is an update to the original Windows 3.1 Media Player. Media Player 2.0 allows a user to play, pause, rewind, and fast-forward video clips, or sound, by simply opening the particular media file and using its VCR-like controls to run the media object. The key enhancement makes Media Player 2.0 OLE compatible, so that video clips can be inserted into other applications. This technology is discussed in the next section.

2. Object Linking and Embedding (OLE)

Object linking and embedding, pronounced "Olay", like the bull-fighter's shout, is one of the most important developments for creating multimedia applications. Put simply, OLE allows a user to drag objects, such as video clips, images, and sound clips,

from one OLE application (called the source) to another OLE application (called the target) [Ref. 19:p. 1]. This is important because it allows multimedia objects, like video clips, to be embedded in other applications and played by double-clicking with the mouse on top of that media object. For instance, by copying an AVI file to the Windows Clipboard, and then using the "Paste Special" option from any OLE-compliant application's Edit menu, that particular video file becomes now embedded into that application. The video file appears in the application in a viewing window, and by double clicking on the video frame, the OLE process starts the Media Player from within that application.

E. LIMITATIONS AND SHORTCOMINGS OF DIGITAL VIDEO

The most obvious limitation of digital video is the file-size of capture video. Even by employing compression, video files of any significant length can easily exceed 30 megabytes. At that rate, even the reasonably large hard-disk drives (500 MB) could hold only a small number of video files. Because of this limitation, digital video must be used sparingly. Table 3 illustrates the file-size comparison of video captured at 15 fps in varying sized viewing windows and durations. In instances where 10 seconds of quality video will add impact to an application, it is well worth the 2 or 3 megabytes of disk space. These instances must, however, be chosen carefully.

One solution to the storage problem of digital video utilizes CD-ROMs. A CD-ROM's 600-plus megabytes of storage accommodates hundreds of video clips, but at a price. Access speed and data-transfer rates, discussed earlier, are much slower than

hard-disk drives, contributing to slower video playback rates. Additionally, CD-ROMs limit the portability of the multimedia application. These considerations are discussed in depth in Chapter VI.

TABLE 3. VIDEO FILE SIZE VS. VIDEO DURATION FOR DIFFERENT SIZED VIEWING WINDOWS USING INTEL'S INDEO CODEC

Indeo Codec without sound at 15 fps: duration	320 x 240 sized viewing window: file size in megabytes	240 x 180 sized viewing window: file size in megabytes
10 seconds	3.335 MB	2.004 MB
20 seconds	6.825 MB	4.018 MB
30 seconds	9.955 MB	6.076 MB
60 seconds	20.139 MB	12.148 MB

Another shortcoming of digital video arises because the fastest CPUs only permit 30 fps in quarter screen viewing windows. While these windows are large enough to display video without causing the viewer to squint at the screen, users of video expect more for the amount of money invested [Ref. 13:p. 52]. Until codecs are developed that permit 30 fps playback in full-sized viewing windows (such as MPEG) at affordable prices, digital video's usefulness in multimedia applications will remain a novelty.

One more limitation of including digital video in multimedia applications pertains to the cost of obtaining quality video. Obtaining quality video requires more than simply connecting a VCR or video camera to a PC and capturing video. These considerations are described in the next section.

F.   OBTAINING QUALITY VIDEO

Obtaining quality video for use in multimedia applications is not as easy as just taking analog video off a tape and capturing it digitally to disk.   Producing quality video can involve a dozen professional video crew members and thousands of dollars.   This does not even take the PC hardware into account.   Video for PC multimedia applications can be as simple and inexpensive as the creator desires.   But professional quality video usually means involving professionals.

Digital video production sources recommend creating a multimedia team that includes a producer, graphic artists, a writer, an audio engineer, a video engineer, a lighting expert, and camera operators [Ref. 5:p. 560].   Estimated costs for production crew members range from $75 to $150 dollars per hour [Ref. 1:pp. 310-311].   Typically, multimedia software titles cost between $200,000 and $500,000 dollars to produce [Ref. 1:p. 300].   In terms of time, industry sources state that the general rule of thumb for scripted productions, such as training videos, is five to six minutes of edited video per day [Ref. 13:p. 313].   This translates to 3 days of shooting for 15 to 18 minutes of video.

Obtaining video for an application like the MAES is even more difficult. Assuming that a professional production crew will be used, the additional costs of security clearances must be considered.   Fortunately, most military commands have support staffs that can substitute for professional production crews.   The cost in man-hours though, is still considerably high.

53

Once the video is recorded and edited it must still be converted to digital format. If professional quality video editing hardware is not available, this is best left to a video service bureau. Depending on the amount of video involved, this service can range from $1000 to many thousands of dollars.

As evidence of the risk of using amateurs to obtain video, the following example is provided. During the course of researching video production for this thesis, the author met with several MK 92 engineers at the MK 92 Test Site in Port Hueneme, California, in order to obtain sample video. Including lighting setup, readying the MK 92 gear for shooting, and obtaining the desired results for the particular scenario of the MK 92's DSOT procedure, the total time and effort expended to tape 10 minutes of potentially usable video required 3 hours and 4 personnel. Upon review of the tape, however, it became apparent that the quality of the video was not suitable for use. If professional video production personnel and a detailed script had been employed, this effort might not have been wasted.

G.   APPLYING DIGITAL VIDEO TO THE MK 92 MOD 2 MAES

Using digital video in future implementations of the MAES is definitely worth pursuing. Just as graphic images can enhance the meaning of MAES procedures and instruction, video will add the benefit of motion, and possibly sound, to clarify key points. Even very short video clips could serve to clarify the meaning of some textual descriptions in the MAES.

As with the photos, diagrams, and illustrations described in Chapter III, videos would ideally be displayed in the center of the screen and invoked through the use of a clearly labeled button. There is one serious obstacle, however, preventing the incorporation of digital video in the MAES.

Because the current version of Adept is not OLE compliant, it is impossible to embed video into the Adept displays. Figure 10 demonstrates how video might be used in future versions of the MAES built with an OLE compliant Adept. In this case, the
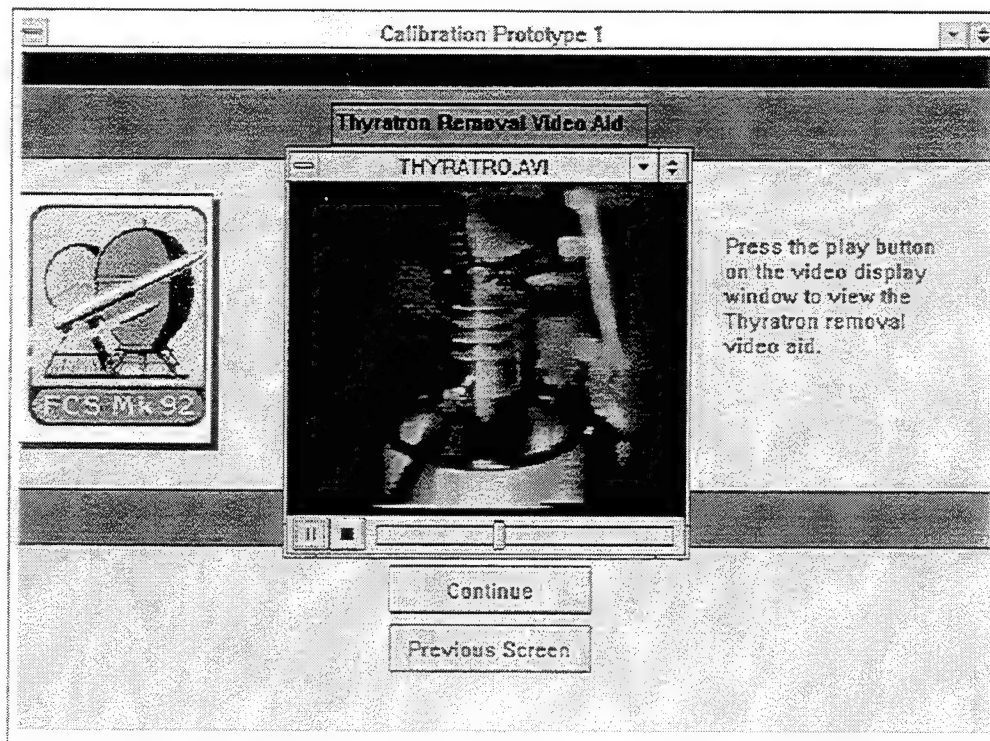
Figure 10. Simulation Screen of Video Clip in MAES with OLE

video window centered in the screen would appear whenever that particular display is accessed. This would allow the user to control the playback of video without moving the

position of the video on the screen or accidentally sending the video clip to the background. The danger of doing this is described later. By double clicking on the video window or using the start or pause button, the user could view the video, and, when the video stops playing, could either replay the video or continue on to the next screen.

Figure 11 shows what happens when video is currently invoked in Adept without OLE. A video clip is invoked by programming a "custom" Adept node using
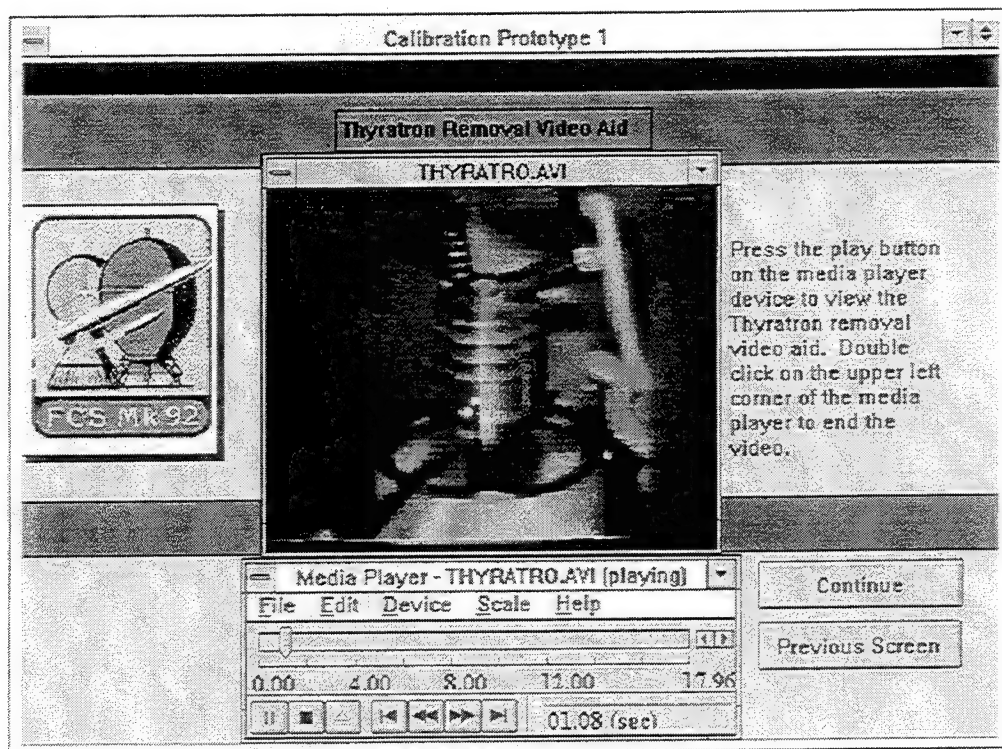
Figure 11. Video Clip imported in MAES without OLE

Adept's script language for the "Run Program" option. While it is very easy to program the script necessary to import video into Adept, a number of deficiencies and potential problems result. First, the Media Player (directly beneath the video in Figure 11) must be

used instead of the easier start/pause buttons available with OLE. This alone does not sound like a serious drawback; but since the video is not embedded into the display, the user could accidentally move the display window or alter the video playback settings by accessing the Media Player's control options.

Secondly, and more importantly, since the "Run Program" option merely halts Adept and starts some other application (in this case, the Media Player) if the mouse is clicked anywhere on the screen other than the video window or the Media Player, Adept is brought to the foreground. The danger here is that the Media Player with the video clip loaded is now running in the background. This consumes valuable memory and could slow down the performance of the MAES. Furthermore, an unsuspecting user, when confronted with the disappearing video clip, might invoke another instance of the Media Player and video and make the same mistake again. The only way to close these videos, once sent to the background, is to close Adept, and then close each separate instance of the Media Player and video. Finally, since the video is not embedded in the display screen, the Media Player and video window appear in different positions each time they are invoked. Appendix B will provide detailed instructions for bringing video into the MAES without OLE.

Representatives from SoftSell anticipate the release of an OLE compliant Adept by 1995 [Ref. 25]. Once Adept supports OLE, importing videos into displays will be as easy as pasting an object from the Windows clipboard. This video however, will be embedded in the display by the Adept programmer, and the user will no longer be able to alter this

display in the run-time version, as is possible now. Another shortcoming of the lack of OLE support occurs in maintaining video files. This is discussed in the following section.

H.   MAINTENANCE OF VIDEO IN THE MK 92 MOD 2 MAES

Chapter III described possible maintenance required for graphic images used in the MAES. The same maintenance applies to video files. When new instances of video are determined to be necessary, new video will have to be acquired, and new Adept screens will have to be built by an Adept programmer. Another possibility that will require updating the video is if a change to the configuration of the MK 92 Mod 2 FCS occurs. Here too, new video would have to be acquired, and new Adept screens built. In its current form (without OLE), MAES "custom" nodes will have to be entirely reprogrammed, with new script code written to invoke the "Run Program" option. Additionally, as described previously, obtaining new video sequences requires significant time and effort.

Future versions of Adept, supporting OLE, will merely require cut and paste operations. Unlike the current version, with OLE, media files will be able to be maintained in locations on the hard-disk other than the Adept directory. This becomes important when considering CD-ROM as a potential storage medium for multimedia files. This is discussed further in Chapter VI.

I.   LIMITATIONS OF DIGITAL VIDEO AND PORTABLE COMPUTING

As discussed in Chapters II and III, advances in portable computer technology have eliminated many of the restrictions from achieving desktop comparable performance on portable PCs. With the aid of powerful 486DX2 and DX4 Intel CPUs, notebook or laptop computers can achieve playback rates of 30 fps in 320 x 240 sized windows. For a price, Pentium equipped portables, capable of playing 15 fps in 640 x 480 sized windows, are already available [Ref. 26:p. 34]. Coupled with the necessary display drivers to produce the minimum 256 shades of gray or color and large, fast hard-disk drives, portable PCs are more than capable of handling digital video. Once again, all of these factors contribute to higher price and shorter battery life, but as technology improves and competition thrives, these limitations will disappear [Ref. 17:p. 2]. As mentioned earlier, there are even predictions that video capture hardware, now small enough to fit into only desktop PCs, will eventually be contained on a chip, small enough for any portable [Ref. 23:p. 2]. In the meantime, portable PCs capable of video playback only are available for street prices as low as $1200 dollars.

J.   SUMMARY

This chapter provided an overview of digital video technology, including hardware and software requirements. Additionally, some limitations of current digital video technology, as well as costs of obtaining video for use in multimedia applications, were offered. Examples of problems encountered when incorporating digital video into the current version of Adept were discussed. The anticipation of an upcoming OLE

59

compliant release of Adept, and how it will overcome present problems with video in the MAES was also examined. Finally, discussion on maintaining video for the MAES and the limitations of using digital video on portable PCs was offered. The next chapter discusses sound and its role in multimedia.

V. SOUND

A. OVERVIEW

The previous chapter introduced digital video and its role in multimedia. This chapter deals with the use of digital audio, or sound, in Windows multimedia applications. It provides a background of sound technology and its uses, describes hardware and software requirements, and discusses some limitations of current multimedia sound technologies. Next, the chapter examines how sound might be used in future versions of the MAES, as well as the accompanying maintenance requirements. Finally, it provides a discussion of the limitations of applying sound to a multimedia application on a portable computer.

B. USING SOUND IN MULTIMEDIA

Just as the use of voices in the movie *The Jazz Singer* revolutionized the entertainment industry in 1927, the introduction of sound to the PC ushered in the revolution of PC multimedia [Ref. 5:p. 18]. Until the advent of multimedia sound, most PCs engaged only one human sense: sight, the most subjective of the senses [Ref. 5:p. 19]. Through the use of sound, multimedia enables users to add an emotional element to graphic applications. Sound also enables users to avoid visual overload, as substantial amounts of text can overwhelm viewers and detract from their ability to comprehend graphic images [Ref. 1:p. 28]. Combining vocal narration with graphics to convey a

61

particular point is far more effective than plain text and graphics. "Several studies demonstrate that sound contributes more than half the effect of any graphic image, regardless of the subject matter or the audience" [Ref. 5:p. 19]. If nothing else, sound makes applications more interesting and fun to use.

The previous chapter discussed how analog video is captured to a PCs hard-disk in the form of digital video. Applying sound to multimedia applications requires the same technology. Analog sound, such as music or voice, is converted to digital sound by an audio adapter card (commonly called a sound card), and special software. Sound cards and their controlling software are described later in this chapter.

Since the MAES operates in a Microsoft Windows environment, this chapter restricts its discussion to audio formats recognized by Windows. The three most common types of digital audio used in Windows are waveform (WAV) audio, MIDI (Musical Instrument Digital Interface), and compact disc digital audio (CD-DA).

1. Waveform (WAV) Audio

Waveform audio is analog sound (voice or music) converted and stored in a digital format by using a sound card. This digital sound can be manipulated using WAV audio editor software. Waveform audio is captured or "sampled" by hardware on the sound card called an analog to digital converter (ADC). Similarly, WAV plays back through hardware on the sound card called a digital to analog converter (DAC). The WAV sound is heard by amplifying it and playing it over speakers. Waveform audio files in Windows have the .WAV file extension and are easily sampled from sources

including microphones, tape decks, or audio CD players. Common "sampling rates" include 11.025 kHz, 22.05 kHz, and 44.1 kHz. Higher sampling rates produce better sound fidelity, but at the expense of consuming greater disk space [Ref. 5:p. 46]. Additionally, the sound resolution, or the number of bits a sound is sampled at determines the precision of measurement of the recorded sound [Ref. 5: p. 46]. Sampling resolutions of 8-bits provide 256 individual amplitude measurement intervals for each sound and produce monaural audio [Ref. 5:p. 46]. Sampling at 16-bits provides 65,536 different levels and stereo audio [Ref. 5:p. 46]. Higher sound resolutions increase the amount of disk space required to store the sampled WAV [Ref. 5:p. 46]. Microsoft's Video for Windows, discussed in the previous chapter uses WAV audio in the interleaving process to create AVI video files. Waveform audio is the most common type of sound used in Windows multimedia applications [Ref. 5:p. 180].

2. MIDI (Musical Instrument Digital Interface) Audio

The second most common Windows sound format is the Musical Instrument Digital Interface (MIDI). MIDI is an international standard established in 1982. It specifies the cabling and hardware for connecting computers and electronic musical instruments, and the set of rules that controls the exchange of messages between the PC and the MIDI devices. Because MIDI is used strictly for musical multimedia applications, it is not considered suitable for use in the MAES.

3. Compact Disc Digital Audio (CD-DA)

Compact Disc Digital Audio (CD-DA) (often referred to as Red book audio for the specification defined in Philips N. V.'s red-bound book) is the digital sound format used by standard audio CD's. This type of audio does not come in a standard file format, but must be accessed from the compact disc through Windows applications, such as the Media Player. Red book audio provides a source for multimedia applications that require top quality sound, and is most often used for soundtrack and music. The nature of the types of sound which might be implemented in future versions of the MAES preclude the need for the use of CD-DA. Even if future versions of the MAES are distributed on CD-ROM for their advantageous storage capabilities, the sound type will most likely be WAV audio accompanying videos, or short voice WAV files.

C.   HARDWARE REQUIREMENTS FOR SOUND

A brief description of the technology required to capture and playback sound on PCs has already been provided. Basically, sound from an external source such as a microphone or tape player is input to the sound card via an input jack. The sound card's ADC and accompanying software "samples" or records the sound, and stores it on the PC's hard-disk. The "sampling rate" refers to the frequency at which the sound is recorded. Higher sampling rates achieve higher quality sound. The 16-bit ADC sound specification for MPC allows sampling and playback rates up to 44.1 kilohertz (kHz), enabling high quality stereo sound. Sound cards with 8-bit ADCs permit sampling rates of up to 22.05 kHz, more than adequate for voice playback. Higher sampling rates also

64

produce larger sound files. Fortunately, captured sound can be stored in compressed format with the aid of codec software.

Once the sound is stored digitally on the PC's hard-disk, it is played back by employing the reverse process described above. The sound card uses its DAC to convert the digital sound data to audible analog sound with the aid of a small, onboard amplifier, and external speakers or earphones. The sound is played back at the same frequency at which it was sampled. If compression was used to store the file, a software codec would decompress the data.

Table 1 in Chapter II provided the MPC specifications for sound hardware in multimedia PCs. Today, sound cards meeting MPC requirements are available for prices as low as $25 dollars [Ref. 27: pp. 213-220]. Sound cards meeting MPC2 specifications can be obtained for prices as low as $70 dollars [Ref. 27:pp. 213-220]. External speakers or headphones for PC sound are available for as low as $5 dollars [Ref. 27:pp. 213-220].

As sound and miniaturization technology improves, the physical size of sound cards decreases. Today, many of the new portable PCs are shipping with internal 16-bit sound cards and microphones, with input jacks for other sound sources included. These "multimedia ready" portables are available for prices as low as $2000 dollars [Ref. 28:p. 1].

Other portables with Personal Computer Memory Card International Association (PCMCIA) slots can use PCMCIA sound cards. These cards provide miniaturized storage and peripheral I/O capabilities for portable PCs. The drawbacks to PCMCIA

cards include the expense (upwards of $150 for 8-bit, and $300 for 16-bit), the need for extra PCMCIA management software drivers to use the card (hence more RAM is required), and the need for external speakers [Ref. 28:p. 2].

D.   SOFTWARE REQUIREMENTS FOR SOUND

Every sound card used in Windows multimedia PC applications requires unique software drivers to control the card's ADC, DAC, and amplifier. For instance, a Creative Labs Sound Blaster card needs accompanying proprietary software drivers to control sampling and playback. Additionally, software codecs aid in reducing sound files by providing compression and decompression algorithms. Software applications such as Windows' Media Player, Recorder, and Mixer are necessary to control the sound in terms of starting, stopping, recording, editing, and volume.   While not necessary to play or record sounds, Microsoft's OLE software, defined in the previous chapter, would allow sounds to be imported more easily into multimedia applications.

Another type of audio software that uses sound to enhance PC applications is voice recognition software.   This software learns, and then recognizes a user's spoken commands.   The user can now use voice commands to perform Microsoft Windows operations, such as opening and closing files.   Currently, however, voice recognition technology for Windows is limited to basic file management commands. Applications, such as Adept, would have to be specifically tailored to support voice recognition for it to be of real use. Additionally, the current process, required to train the voice recognition software to learn the individual user's voice, is time consuming [Ref. 3: p. 275].   Even

then, the success rates for each voice command are less than perfect, and repeated attempts by the user to get the system to recognize a command could lead to frustration [Ref. 3: p. 275]. Furthermore, if the voice recognition learns one user's voice, it becomes difficult for other users of the system to use it [Ref. 3:p. 275]. As the technology in this area improves, and more Windows applications become voice recognition compatible, this type of software will improve productivity because mouse or keyboard usage will decrease.

E.   LIMITATIONS AND SHORTCOMINGS OF SOUND

Improvements in sound technology and fierce competition in the multimedia hardware industry have contributed to making digital audio technology widely available and affordable to most PC users. Even affordable portable PCs with 16-bit sound built-in are available today.   Incorporating sound in multimedia applications is as easy as recording sound with a conventional cassette tape recorder. The only real limitation of using digital audio pertains to the relatively large WAV file size. A typical 5 second audio clip sampled at 11 kHz requires 25 kb of disk-space. The same audio clip sampled at 22 kHz requires twice the disk space. While these files are small compared to video or graphic files, sound must still be used sparingly if storage space is limited. If large amounts of digital audio will be used in an application, CD-ROMs could be used as a storage medium, but this drastically reduces the portability and adds to the cost of the system.

F. OBTAINING SOUND FOR THE MK 92 MAES

Obtaining sound for use in the MAES is a simple and inexpensive task. Once the appropriate sound or voice message is chosen, the MAES developer samples the sound using the hardware and software described previously. Using an 8-bit sound card will provide sufficient audio quality, since most of the sounds for consideration will be voice or simple sound effects. This permits the creation of smaller sound files, or allows more sound files to be stored on the hard-disk. Once the sound is recorded in WAV form, it is ready for distribution.

G. APPLYING SOUND TO THE MK 92 MAES

Just as video and graphics could be used to add visual impact to the instructions and procedures in the MAES, sound could be used to enhance MAES screens by grabbing the user's attention when necessary. Engineers from NSWC's MK 92 team agree that adding sound to the MAES will add impact, and make it more interesting to use [Ref. 29]. Figure 12 displays a typical warning screen in the MAES. An accompanying sound clip (either a voice and/or an alarm), warning the user of the danger involved, would add emphasis to the message. Ideally, this sound would play automatically when that particular MAES screen is displayed.

But, just as it is currently very difficult to add video to the MAES, due to the lack of support for OLE, it is also difficult to add sound to applications created with the current version of Adept. In its current form, sound can only be added to the MAES by manually invoking the Windows Media Player, and then, with all the accompanying

problems described in Chapter IV (Appendix B contains instructions for importing sound

into Adept). SoftSell predicts a future release of Adept supporting OLE by 1995. With

OLE, sound can be easily imported and embedded into Adept screens, and will have the

ability to play automatically when screens are opened, vice having to be activated

manually with buttons.
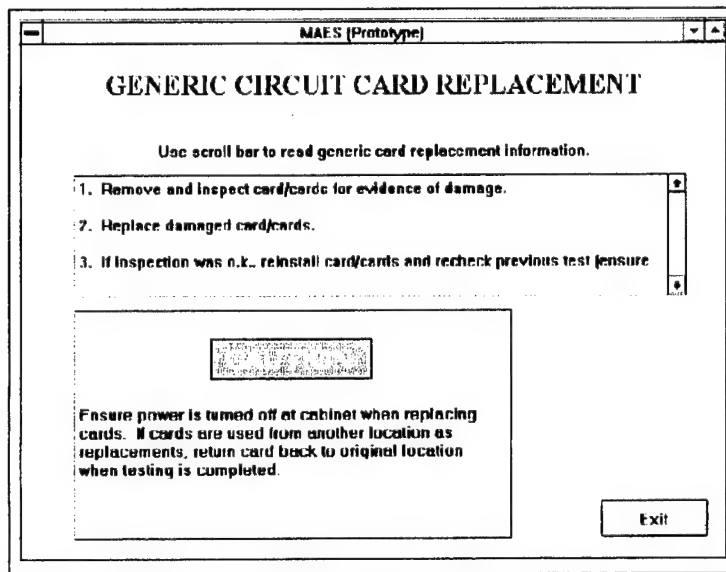
Figure 12. Example of MAES screen where sound would
add impact

As voice recognition software technology improves, and if future versions of Adept

support it, incorporating voice recognition into the MAES would be a valuable

enhancement. With voice recognition, a user of the MAES could progress through the

diagnostic process without having to use the pointing device or keyboard. This would

save the user time, and make the program simpler to use.

H. MAINTENANCE OF SOUND IN THE MK 92 MOD 2 MAES

Just as images and videos used in the MAES will eventually need updating or deleting, sound files will require the same types of maintenance. New sounds will have to be sampled by the MAES development group and programmed into Adept. Without OLE, this is a considerable task, but future versions of Adept that support OLE will allow easy incorporation of sound in MAES screens. Until that time, any maintenance for sound files will have to be conducted in accordance with Appendix II.

I. LIMITATIONS OF SOUND AND PORTABLE COMPUTING

As discussed previously, digital audio is becoming an inexpensive option for portable PCs. Portables with built-in sound cards, microphones, and speakers are the ideal multimedia platform. Portables with PCMCIA slots can use PCMCIA sound cards, but these cards are expensive, and reduce the portability of the system.

The physical size of digital audio files requires the use of compression, but compression does not reduce the quality of sound. Even so, these sound files are small compared to graphic and video files. Hard-disk drives larger than 200 megabytes should accommodate the required programs, images, and sound files. If there are enough sound files, a CD-ROM drive may be used for storage, but this will reduce the portability of the system. Chapter VI, however, will illustrate some new portable CD-ROM technologies that do not limit the mobility of portable systems.

On the plus side, using sound is not a RAM intensive process, so a PC with 4 MB of RAM would have no difficulty recording or playing sound. Furthermore, the CPU

speed has no effect on sound capability, so even the slowest 286 computers can record and play sound.

J.   SUMMARY

This chapter provided a description of current digital sound technology for the Microsoft Windows environment. The different types of Windows sound formats, as well as hardware and software requirements for using sound were also provided. A discussion of some of the limitations of using sound for multimedia in the Windows environment revealed that improved technologies and low prices have eliminated many of the restrictions placed on graphics and video. The next section described how to acquire sound files for Windows applications. Examples of how sound might be incorporated in future versions of the MK 92 Mod 2 MAES, and the impact of the lack of OLE support in Adept were the subject of the following section. Finally, the chapter discussed maintaining sound files for the MAES and the limitations of using sound in portable computing applications.

VI. CD-ROM

A. OVERVIEW

This chapter provides an examination of CD-ROM technology, including the costs and benefits of using CD-ROM. It also examines how CD-ROM technology could be applied to future implementations of the MK 92 Mod 2 MAES. Next, the chapter discusses maintenance concerns of CD-ROM applications. Finally, the chapter provides some of the limitations of using CD-ROM technology in a portable computing environment.

B. CD-ROM TECHNOLOGY

CD-ROM technology was introduced by Philips N.V., a Dutch company, in 1983. CD-ROMs were derived from another of Philips' inventions, the laserdisc. Basically, a semiconductor laser and a photoreceptor are used to read data in the form of minute pits in the surface of highly reflective discs.

The laser, an acronym for light amplification by the stimulated emission of radiation, creates a beam of coherent light aimed at a reflective surface located at the top of the disc. Coherent means that the light waves are highly organized, not the random jumble of waves emitted, for instance, by a light bulb. The light reflected by the pits interferes with the light reflected by the normal surface of the disc. The interference is detected by a photosensitive component, which converts the light signals into binary bits. The size of the pits is exceedingly small--30 pits equals the diameter of a human hair--and about 2 billion pits are on a typical audio CD [Ref. 5:p. 86].

CD-ROMs were originally intended as a mass-storage medium for personal computers. Prior to 1991, virtually all CD-ROMs were devoted to encyclopedic and bibliographic titles such as full-text reproductions of books, periodicals, and large databases [Ref. 5:p. 88]. The data on early CD-ROMs consisted only of text.

Not long after the first CD-ROMs were issued, it became evident that a combination of text and graphic images could be used to create products that would appeal to consumers, and thus expand the market for CD-ROM publications. Because the recording format for compact disc, digital audio (CD-DA) was well established, sound could be added to enhance the presentation [Ref. 5:p. 89].

At this time, a number of standards began to emerge. First, the CD+Graphics standard was established. Later, Microsoft, Philips, and Sony combined their technical teams to create the CD-ROM extended architecture (XA) standard that enables audio, text, and graphic images to be interleaved within a single file. While other standards, such as Kodak's Photo CD and Philips CD-Interactive (CD-I) are emerging, conventional CD-ROM, and CD-ROM XA formats are the preferred choice for creating PC-based Windows applications, and are the standards established in MPC and MPC2 specifications, respectively. The remainder of this chapter concentrates on these formats.

Data on CD-ROMs is organized into tracks that contain 24-byte frames, played at a rate of 75 frames per second. Data can include sound, text, graphics, and video. Conventional CD-ROM drives store each type of data in separate tracks. CD-ROM XA enables interleaving of different types of data in one track. A sector of data, similar to a

sector on a PC's hard-disk, consists of 98 frames and results in 2,048 bytes for user data (after synchronization data, header data, and error detection and correction data). The theoretical maximum number of sectors on a CD-ROM is 330,000, allowing a maximum disc storage capacity of 660 megabytes. Not only does this large capacity facilitate the large size of multimedia files discussed in previous chapters, but it provides an attractive distribution medium. An application that once required many installation floppy diskettes, now requires only one CD-ROM disc.

In addition to the common names of the different CD-ROM formats, CD-ROM drives and the specifications for the media with which they are compatible are "color-coded" based on the color of the covers of the Philips publications that describe their formats [Ref. 5:p. 90]. "Red book" or CD-DA was described in the previous chapter. The two "color-coded" standards considered in this chapter are Yellow book and Orange book.

1. Yellow Book CD-ROMs

Yellow book CD-ROMs correspond to the conventional CD-ROMs, and CD-ROM XA format, discussed previously. They are capable of storing data in the form of files that can be translated to conventional DOS, Macintosh, or Amiga file structures. The translation is accomplished by a software driver, such as Microsoft's MSCDEX.EXE (for Microsoft CD extension) which is required on all IBM-compatible multimedia computers. Double, triple, and quadruple speed CD-ROM drives, discussed in Chapter II, fall into this category.

74

2. Orange Book CD-ROM Drives

Orange book drives are capable of writing to CD-ROMs. Orange book 1 drives are erasable and rewritable. Orange book 2 drives use CD-ROMs that have a specific type of surface designed for write-once operations (thus the abbreviation CD-WO or WORM for Write Once, Read Many). These are important, because Orange book drives permit the publishing of affordable CD-ROM applications.

C. LIMITATIONS OF CD-ROM TECHNOLOGY

This section describes the two primary limitations of current CD-ROM technology: relatively slow performance and high production costs.

1. Performance Issues and CD-ROM

Chapter II described the lack of MPC specifications for data-transfer rates and access speeds of hard-disk drives. These specifications for CD-ROMs, included in MPC and MPC2 standards (see Table 1), constitute one of the primary limitations of CD-ROM technology. The fastest CD-ROM drives available today produce access speeds close to 150 ms and data transfer rates of 600 kbps. Even low-cost hard-disk drives produce access speeds in the sub-12 ms range, and data transfer rates in the 2-3 megabytes per second range.

Thus, the tradeoff of the massive storage capability of CD-ROMs is speed. Older CD-ROM drives conforming to MPC specifications caused prolonged waits by the user while data was processed and displayed. Today, MPC2 compliant CD-ROM drives playing multimedia Windows applications, are not intolerably slow, and can reproduce

75

acceptable video, sound playback rates, and large data retrievals without an irritatingly long waiting time (less than 2-3 seconds waiting time in the $250-$500 price range) [Ref. 27:p. 221].

2. Production Costs of CD-ROM

While doublespeed CD-ROM drives are available today for less than $100 dollars, and triple and quadruplespeed drives range from $300-$600 dollars, the cost prohibitive aspect of CD-ROM technology is in their production. Multimedia developers have two choices when mastering CD-ROM applications: they can make their own or contract with a CD-ROM manufacturer. If low-volume production (less than 100) is anticipated, Orange book CD-ROM drives, available today for less than $4000 dollars [Ref. 30], should be used. The benefit here is that once the initial large cash outlay is made, second pressings or updates of applications cost only the amount of the actual writable disc (approximately $1.50). If hundreds, or thousands of CD-ROMs are required, the time saved by using professional CD-ROM manufacturers may be worth the price. The cost for a master copy produced by a CD-ROM manufacturer varies depending on the number of discs desired. For example, if a developer requires 5000 CD-ROMs, the cost may be $2000 dollars for the master and $1.25 for each copy. The limitations of CD-ROM technology and portable computing are discussed later in this chapter.

D. APPLYING CD-ROM TECHNOLOGY TO THE MK 92 MOD 2 MAES

If the types of multimedia discussed in this thesis are eventually incorporated into the MAES, storing these relatively large files may become a problem. One alternative to limiting the amount of multimedia data to the relatively small hard-disk drives of portable PCs pertains to the use of CD-ROM as the storage medium. As discussed earlier, each CD-ROM disc is capable of storing up to 660 megabytes of data. Capacity of this size is more than adequate to facilitate storing hundreds of multimedia files, the MAES program, the PC's operating system files, and Microsoft Windows. As mentioned earlier, a CD-ROM disc provides an excellent distribution medium. If used in this manner, a single CD-ROM disc loaded with all of the MAES program files and supporting software could save the user time and frustration during the installation process. In the future if files on the host PC's hard-disk are corrupted, the system could be easily reinstalled with one CD-ROM disc.

Furthermore, if it is determined that the data contained in the MAES application is classified, storing the entire application on a CD-ROM disc would ease security restrictions, by separating the data from the actual host PC. The classified disc could be securely locked up in the proper container, while the PC could be stored separately. Additionally, the large capacity of a CD-ROM disc prohibits copying, and any attempts at tampering with the data on the CD-ROM renders it useless.

E. CD-ROM MAINTENANCE CONCERNS

The maintenance considerations of CD-ROMs involve two issues: the CD-ROM software and hardware. If the MAES, or parts of the MAES are distributed on CD-ROM, any future upgrades to the system would require the re-mastering and duplication of new discs. This becomes an expensive proposition if frequent updates or changes are necessary. A solution to this would involve sending out minor corrections to the program on diskette. Problems would arise here, if the MAES program, and the multimedia files are run off the same disc. If the MAES program is stored on the hard-disk, and multimedia files are stored separately on CD-ROM, changes in the program would not affect the disc, and could be distributed via floppies. If the changes or additions to the multimedia are not significant enough to warrant pressing a new CD-ROM, they too, could be distributed to the users in compressed format on floppy disks.

The second maintenance issue for CD-ROM involves the physical maintenance of the CD-ROM drive and disc. If the CD-ROMs are used for the MAES and the drive or disc fails, the drive would require replacement. In the meantime, the system would be useless. Unless it is a minor fault, repair of CD-ROM drives is beyond the capabilities of shipboard electronics technicians (ET's). Considering typical shipboard conditions, the failure rate of CD-ROM drives would likely be higher than the 10,000 hours mean time between failure (MTBF) specified by MPC2 standards.

For deployed FFG's, a malfunctioning CD-ROM drive or disc would render parts of, or the entire system, unusable. Any version of the MAES distributed solely, or partly

on CD-ROM would have to include contingency plans for replacement CD-ROM drives and discs in the event of failure. Designating a tender, or the carrier, as the battlegroup computer spare parts and software repository, and stocking them accordingly for deployments provides one solution to this potential dilemma. The relative fragility of CD-ROM drives with respect to their being deployed with a portable system is a major drawback, and is discussed in the following section.

F. LIMITATIONS OF PORTABLE COMPUTING AND CD-ROM

While affordable, portable CD-ROM drives are available today, the real cost of CD-ROM technology is the effect it has on accommodating portable computing, especially in the shipboard atmosphere of the MAES. Most portable CD-ROM drives are external to the actual PC. While the Sony Corporation offers a portable model that incorporates the CD-ROM player under the keyboard in an integral unit, the $5000 dollar price tag is prohibitively high [Ref. 31].

External, portable CD-ROM drives would limit the ability of the enlisted FC to take the MAES to remote equipment locations of the MK 92 MOD 2 FCS. Furthermore, while portable PCs are relatively durable, dropping a portable CD-ROM drive usually causes significant damage [Ref. 28:p. 4]. Additionally, unless alternating current outlets are widely available, portable CD-ROM drives account for significant battery drain [Ref. 28:p. 4]. Add to this, the complications of the additional software drivers required to manage the PCMCIA interface cards (required to connect most portable CD-ROM drives

to potable PCs), and the subsequent decrease in available RAM. The limitations of portable computing and CD-ROM technology become sizable.

G.   SUMMARY

This chapter provided a brief examination of CD-ROM technology and suggested some of the costs and benefits associated with it. It also provided examples of how this CD-ROM technology could benefit, as well as detract from the effectiveness of the MAES. Finally, the chapter offered maintenance considerations of CD-ROM technology and limitations of CD-ROM in a portable computing environment.

VII. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This thesis has attempted to examine the feasibility of incorporating multimedia in the MK 92 Mod 2 Fire Control System Maintenance Advisor Expert System.

Chapter II provided definitions of multimedia, and examples of its importance. It also discussed the current standards for IBM-compatible multimedia hardware, and examined the limitations of these standards. Finally, it offered an explanation of the role of standards, and the importance of keeping them up to date.

Chapter III offered an in-depth examination of the use of high-resolution graphics in multimedia applications. It provided a discussion of the minimum hardware specifications needed to display graphic images on IBM-compatible PCs, including portables. It also outlined the different types of graphic formats supported by Adept and described the advantages or disadvantages of each type. Next, the chapter examined methods of acquiring the different types of prospective graphics, and how they would be implemented in future versions of the MAES. Finally, the chapter explored the maintenance requirements for graphics in the MAES and discussed the limitations of using graphics on portable computers.

Chapter IV provided a discussion of digital video and its role in multimedia. It discussed the hardware and software requirements for employing digital video, as well as

the current limitations of digital video. Next, the chapter examined how quality video would be obtained and applied to the MAES. Finally, it explored maintenance issues for digital video and the limitations of using digital video in a portable computing environment.

Chapter V discussed the role of sound in multimedia and defined the different formats of sound used in IBM-compatible PCs. It examined the hardware and software requirements for employing sound in multimedia, and how to obtain that sound. Next, it provided a discussion of how sound could be applied to the MAES. Finally, it explored the maintenance issues of employing digital sound in the MAES and discussed the issues of using sound with a portable computer.

Chapter VI examined CD-ROM technology. It also explored the feasibility of applying CD-ROM to the MAES. Finally, it examined costs associated with CD-ROM production, as well as the limitations of using CD-ROM in a portable environment.

B. CONCLUSIONS

The primary research question of this thesis asked: What is the technical feasibility of incorporating multimedia, including high resolution images, digital video, sound, and CD-ROM technology in the MK 92 Mod 2 Fire Control System Maintenance Advisor Expert System? Additionally, it explored the costs of including multimedia and the limitations that a portable computing environment places on multimedia technology.

The central conclusion of this thesis supports the prospect that limited amounts of multimedia applied to the MAES, in the form of high-resolution, gray-scale graphics is an

82

attainable goal. The current version of Adept supports the implementation of many high-quality graphic formats. Building screens that incorporate graphics for the MAES is an easy task. Additionally, most portable PCs have the capability to display high resolution gray-scale images, or can be easily upgraded to do so, by obtaining the proper display driver software from the manufacturer. While color graphics would be preferred, gray-scale images provide quality similar to black and white photography, and are more than adequate to deliver impact and information to the user.

Obtaining suitable graphic images requires nothing more than a photographer, to take pictures of the desired objects, and scanning hardware. The other feasible alternative would be to use a digital frame capture device. Both of these options are already available to the MK 92 engineers at NSWC Port Hueneme, so there would be no additional costs required. Given the limited resources available for distributing the MAES to the fleet on portable PCs and the high cost of the more capable portable PCs required to support the other media, graphic images are the only media that can be employed without significant additional costs or hardware burdens.

While the technology to support digital video and sound in portable PCs is present today, costs for these systems and the supporting hardware would severely limit the ability to deploy these systems to the fleet. Additionally, the current technology for video playback, even in desktop PCs, is limited to quarter-screen sized viewing windows. While this size is adequate to display meaningful video, waiting until technology improves and costs decrease is a more prudent action. Furthermore, the inability of

Adept, in its current version, to easily support video or sound make them unattractive media choices. Without support for OLE, building MAES screens incorporating digital video or sound would require too much additional burden on the Adept programmer, and assume too much knowledge of Windows for the user. Even if the MAES user is familiar with Microsoft Windows and the Window's Media Player, the risks described in Chapters IV and V of media instances (like video) running in the background and sapping valuable memory and processor resources are significant enough to make the MAES "user-unfriendly." Add to this the costs associated with maintaining digital video and sound, and they become unattractive options. However, as the costs of the more capable portable PCs fall, and a version of OLE-compliant Adept is released, these options should be vigorously considered.

Because of the current shortcomings of applying video or sound to the MAES, employing CD-ROM technology to the MAES is unwarranted. The typical 120, 170, or 200 megabyte hard-disk drive available on most of today's portable PCs accommodates graphic images alone. Even if future versions of the MAES do include video or sound, buying portables with larger hard-disk drives and using compression software would be a more attractive option, because of the immediate decrease in mobility that CD-ROM drives contribute to a portable PC. Combine this with the relative high cost of portable CD-ROM drives, the fragility of CD-ROM hardware, and the shipboard environment in which it would be deployed, and it is an especially unattractive option.

C. RECOMMENDATIONS

Given that employing high-resolution graphics in future implementations of the MK 92 Mod 2 MAES is currently feasible, and employing digital video and sound in the MAES is technically feasible, but cost prohibitive, the following recommendations are provided:

1. Graphics

In accordance with the discussion of graphics and digital images provided in Chapter III, gray-scale, GIF images are the recommended graphic format for use in the MAES. The small file-size advantage of the GIF format makes it an excellent choice as it allows for the greatest number of images, given limited hard-disk space. These images should be obtained by either digital frame capture, or conventional photography and digital scanning.

Appendix A identifies recommendations from MK 92 Mod 2 FCS engineers at NSWC Port Hueneme, of specific instances where digital images will provide immediate impact to the MAES. It includes the rationale for choosing the image, as well as where the particular image would appear in the MAES. These images should be considered for immediate implementation into future versions of the MAES. In addition, the instructions for building Adept screens that employ graphics, provided in Appendix B, should be followed.

It is particularly important that the host PC for the MAES application be capable of displaying a minimum of 256 shades of gray (gray-scale) or 256 colors. During the

course of research for this thesis, it was discovered that even portables that advertise only VGA displays (or 16 shades of gray), could be upgraded to display adequate gray-scale or color images by simply updating the software display drivers. Given this fact, purchasing portable PCs with the most capable, affordable display screen is recommended. As Chapter III discussed though, the display screen is not the primary contributor to acceptable graphics. Any portable PC considered as host for future versions of the MAES incorporating graphics must have a display card, or display circuitry built-in, which can accommodate a minimum of 256 shades of gray or 256 colors. This means the video display card must have a minimum of 512 kilobytes of onboard memory, with 1 megabyte preferred. Appendix C provides a detailed checklist of recommended, not necessarily the minimum, portable PC hardware requirements necessary to host multimedia applications. Given the choice between monochrome or color portable displays, color is recommended. In view of the limited budget available for fielding the MAES, portables with monochrome that are capable of 256 shades of gray are the best current choice.

2. Digital Video

Given the current limitations of digital video with regards to portable computing, cost, and lack of support by Adept, it is not currently feasible to incorporate in the MAES. It is recommended, however, that the state of digital video technology be closely monitored, as the promise of affordable MPEG video compression, capture, and playback make it a viable option for the future. When and if digital video technology

86

improves and becomes affordable, and a version of Adept easily supports it, a re-examination of the use of video in the MAES should be conducted. Appendix C provides recommendations for the necessary hardware required for digital video playback on portable PCs.

3. Sound

While it is not currently feasible to employ sound in the MAES, due to shortcomings in Adept and added costs of the portables, this technology should be watched. If voice recognition technology improves and is supported by future versions of Adept, it will add significantly to the ease of using the MAES. At the present time, however, digital sound is not recommended for employment in the MAES.

4. CD-ROM

Because CD-ROM is most valuable as a mass-storage medium, and graphics are the only currently recommended form of multimedia for the MAES, this technology is not recommended for consideration in current or future implementations of the MAES. Not only is it a costly hardware device, but CD-ROM would significantly detract from the intended portability of the MAES.

5. Final Note

The future of multimedia technology for IBM-compatible PCs remains unlimited. Every day, new technologies continue to flood the market, and as a result, prices of current multimedia hardware and software decrease. At the same time, improvements to basic hardware components, like processors, display screens, and

hard-disk drives, permit desktop-comparable performance on portable systems. As advanced multimedia technologies merge with the improved capabilities of portable computers, the sailors of the future may very well be armed with a formidable weapon in the everlasting battle against equipment casualties. Delivering the expert knowledge captured in the MAES, by means other than strictly text, should bring additional meaning and understanding to the user, in the absence of a physical human expert. Afterall, a long distance telephone call was "the next best thing to being there" for the 1980's. So, a truly multimedia capable MAES, with images, video, and voice, will provide "the next best thing to being there" for the sailor of the late 1990's and beyond.

APPENDIX A. INSTANCES OF MULTIMEDIA FOR THE MK 92 MOD 2 MAINTENANCE ADVISOR EXPERT SYSTEM (MAES)

This appendix consists of specific instances of graphic images, identified by the MK 92 Mod 2 Fire Control System engineers at the Naval Surface Warfare Center, in Port Hueneme, California. These inputs were solicited from the engineers through the use of a questionnaire [Ref. 32]. The questionnaire focused on identifying specific instances where images, illustrations, or diagrams would improve the effectiveness of the MAES. While the findings of the engineers are not comprehensive (due to limited availability of the engineers), the 67 instances identified by the engineers provide, in their view, the areas that would benefit most from images.

While identifying the locations of the prospective images, the engineers referenced locations in the MK 92 Mod 2 "Knowledge Document." The knowledge document is the foundation upon which the MAES was constructed. Although the knowledge document does not exist in a published form, the page references given by the engineers are readily understood by all personnel associated with the MK 92 Mod 2 MAES project.

The following pages contain the transcribed results of the questionnaire. They provide the initial recommended graphic images that should be considered for implementation into the MAES, if and when future versions of the MAES include multimedia.

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Picture showing rear view of CAS DSOT test set (UD412).

How? (Closeup, angle, arrows, etc.)

Closeup, with arrows pointing to cables to be removed when performing Track power checks.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "How" on page SH2F, box 1 and 2, and pages SH2H, SH2I, SH2J, SH2K, SH2S, SH2M, SH2O, SH2P, and SH2Q, box 1, for Track power checks. Also occurs as a "How" on page SH2M, box 1 and 2, and pages SH2O, SH2P, SH2Q, SH2R, and SH2S, box 1, for Search power checks.

Why will the picture or diagram add impact to the MAES?

The current illustration is unclassified, but contained in a classified manual. Also, cables to be removed are not shown in the current illustration.

Other Comments:

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Picture showing rear view of STIR DSOT test set (UD432).

How? (Closeup, angle, arrows, etc.)

Closeup, with arrows pointing to cable to be removed when performing power checks.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "How" on page SH3.B.2, box 1 and 2, and pages SH3F, SH3G, SH3H, and SH3I, box 1, for power checks.

Why will the picture or diagram add impact to the MAES?

The current illustration is unclassified, but contained in a classified manual. Also, the cable to be removed is not shown in the current illustration. Recently discovered that the cable was mismarked on USS Rentz.

Other Comments:

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Picture showing side view of CAS DSOT test set (UD412).

How? (Closeup, angle, arrows, etc.)

Closeup, with arrows pointing to AT1 and AT2 of AR1.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "How" on pages SH2I, and SH2J, box 1.

Why will the picture or diagram add impact to the MAES?

The current illustration is unclassified, but contained in a classified manual. Also, it shows the rear view of UD412/A1A4 with an arrow pointing to AR1. However, the view is upside down. This could possibly result in mistaking AR2 for AR1.

Other Comments:

Could use this side view for UD432 since this area is identical. This applies to the STIR pages SH3G (box 1), and SH3H (box 1).

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Picture showing side view of STIR DSOT test set (UD432).

How? (Closeup, angle, arrows, etc.)

Closeup, with arrows pointing to AT1 and AT2 of AR1.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "How" on pages SH3G, and SH3H, box 1.

Why will the picture or diagram add impact to the MAES?

The current illustration is unclassified, but contained in a classified manual. Also, it shows the rear view of UD412/A1A4 with an arrow pointing to AR1. However, the view is upside down. This could possibly result in mistaking AR2 for AR1.

Other Comments:

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Picture showing bottom view of CAS DSOT test set (UD412).

How? (Closeup, angle, arrows, etc.)

Closeup, with arrows pointing to AT1 and AT2 of UD412/A1A4-AR2.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "How" on page SH3P, box 1.

Why will the picture or diagram add impact to the MAES?

The current illustration is unclassified, but contained in a classified manual. Also, it is hard to see AT1 and AT2. Could possibly mistake one from the other. Might also mistake AR1 for AR2.

Other Comments:

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Picture showing side view of CAS DSOT test set (UD412).

How? (Closeup, angle, arrows, etc.)

Closeup, with arrows pointing to the cables to be removed from UD412/A1A6-U2.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "How" on pages SH2K, and SH2S, box 1.

Why will the picture or diagram add impact to the MAES?

The manual does not say anything about removing cables from U2. U2 must be removed completely in order to gain access to R4 on UD412/A1A6-A4A1.

Other Comments:

95

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Picture of UD412 and UD432 in the servicing position (top, bottom, and rear views, and two side views).

How? (Closeup, angle, arrows, etc.)

Closeup, with arrows pointing to the location of items (circuit cards, modules, cables) that are being checked.

Where in the MAES Knowledge Document does this instance occur?

Applies to all paths for DSOT Calibration and the majority of the Help screens in each path. This is for consideration in future implementation of the MAES when parts data is included.

Why will the picture or diagram add impact to the MAES?

Illustrations are present in the parts manual (IPB), but a lot of time is spent locating each item.

Other Comments:

To find a specific item, the part number must be found using 2 Part 4 of the IPB. Opposite the part number is a figure and item number. The figure is an illustration and the item number is shown with an arrow pointing to where it is located. In DSOT Calibration, the figures are located in 2 Part 2 of the IPB. Also, each figure has numerous item numbers. This would eliminate any confusion.

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

CAS DSOT Test Set, RF Circuit Troubleshooting diagram (Figure 5F0-3-4) from Volume 2 Part 3.

How? (Closeup, angle, arrows, etc.)

Closeup.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "Why" on pages SH2A.1, box 4, SH2B, box 3, SH2C, box 1, SH2F, box 1, SH2H, box 1, SH2I, box 1, SH2J, box 1, SH2K, box 1, SH2M, box 2, SH2O, box 1, SH2P, box 1, SH2Q, box 1, SH2R, box 1, and SH2S, box 1.

Why will the picture or diagram add impact to the MAES?

There is a schematic diagram in the manual, but no reference is made to it in the existing troubleshooting flows. The diagram gives an overall picture of troubleshooting RF circuits of the DSOT Test Set.

Other Comments:

Besides being a good troubleshooting diagram, it is a good diagram to be used for training.

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

STIR DSOT Test Set, RF Circuit Troubleshooting diagram (Figure 5F0-3-5) from Volume 2 Part 3.

How? (Closeup, angle, arrows, etc.)

Closeup.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "Why" on pages SH3A.1, box 4, SH3B.2, box 2, SH3C, box 1, SH3F, box 1, SH3G, box 1, and SH3I, box 1.

Why will the picture or diagram add impact to the MAES?

There is a schematic diagram in the manual, but no reference is made to it in the existing troubleshooting flows. The diagram gives an overall picture of troubleshooting RF circuits of the DSOT Test Set.

Other Comments:

Besides being a good troubleshooting diagram, it is a good diagram to be used for training.

Instances where a picture, illustration, or schematic diagram will improve the effectiveness of the MK 92 Mod 2 maintenance advisor expert system (including calibration, performance, and rf power checks):

What? (Picture, Illustration, or Schematic diagram description):

Portions of the overall RF troubleshooting diagram that show a specific path to troubleshoot.

How? (Closeup, angle, arrows, etc.)

Closeup, isolated area of the overall RF troubleshooting diagram to show the area being checked, or develop a separate diagram for this path.

Where in the MAES Knowledge Document does this instance occur?

Occurs as a "Why" on pages SH2A.1, box 5, SH2B, box 3, SH2C, box 3, SH2F, box 5, SH2H, box 3, SH2I, box 3, SH2J, box 3, SH2K, box 3, SH2M, box 5, SH2O, box 3, SH2P, box 3, SH2Q, box 3, SH2R, box 3, SH2S, box 3, SH3A.1, box 5, SH3B.2, box 5, SH3C, box 3, SH3F, box 3, SH3G, box 3, SH3H, box 3, and SH3I, box 3.

Why will the picture or diagram add impact to the MAES?

The overall diagram is good, but it does not show areas that pertain to a specific path. Showing the operator a diagram of a specific path, gives him a heads up on how he can troubleshoot a problem.

Other Comments:

APPENDIX B. BUILDING MULTIMEDIA SCREENS FOR THE MAES

This appendix consists of detailed instructions from the *Adept User's Manual* [Ref. 33] for building screens that contain multimedia for future versions of the MAES. The first section describes the procedures for building screens that contain graphics. The next section provides the current procedures for enabling video playback in MAES screens, followed by a similar section for playing sound clips. As discussed in Chapters IV and V, the lack of support for OLE requires special script programming in order to play video and sound files within Adept applications.

A. INSTRUCTIONS FOR EMPLOYING GRAPHICS IN THE MAES

This section describes the procedures for incorporating bit-mapped images into MAES screens. The first step requires the programmer (user) to enter Adept's Procedure Builder, and go to the location within the application where the desired graphics are to be placed. Next, the user selects the "display-style" node. If the user desires to keep the same background properties as other MAES screens, he or she selects any other display node, goes to the menu bar at the top of the screen, selects "copy," and then repeats this step and selects "paste." An identical display node appears on the screen. Next, the user selects "Open Display," or double-clicks on the new node to open the display. Now, the user is in the "Display Builder" mode.

The user is now able to edit the display to include bit-mapped images. The Adept "Tools" palette appears in the left-hand corner of the screen. By selecting the "Bitmap object tool," the third button down on the left of the "Tools" palette, the user can drag the mouse or pointing device over the display screen and create a bitmap background. Then by selecting the "Pointer tool" and double-clicking on the newly created bitmap background, the user invokes the "Bitmap Properties" dialog box.

The "Bitmap Properties" dialog box allows the user to choose the type of bitmap image, i.e., BMP, GIF, PCX, (the recommended format is GIF due to its small size in relation to the other image types). The user then selects the location of the file on the hard or floppy disk-drive, and selects "OK."

Now, the new bitmap image appears in the previously created bitmap frame. In order for the application to work properly in the RunAdept mode, the bitmap image must be in the Adept directory. Once the bitmap is on the display, the programmer can use the "Pointer tool" to resize, or relocate the bitmap within the display. If images are too large to fit on a display screen, the user can select a scrollable window as the "Border Style" from within the "Bitmap Properties" dialog box. This allows the entire bitmap to fit in a smaller size window, yet be viewed by scrolling with the mouse or pointing device.

Bitmaps should be placed within MAES screens so as to allow room for any additional buttons, or descriptive text. If the subject of the bitmap is not clear, the user can use the Display Builder's "Text tool" to add any necessary descriptions. If desired, the user can also select the "Draw Objects" option from the "Tools" palette to overlay

shapes, or arrows on bitmap images. Once the user is satisfied with the display, the normal procedures for building links to other nodes (and building buttons) should be followed. Additional questions for importing or displaying images within Adept should be referred to the *Adept User's Manual.*

B.   INSTRUCTIONS FOR EMPLOYING VIDEO IN THE MAES

Importing digital video clips into Adept via object linking and embedding (OLE) is not currently supported. Ideally, future users of Adept will be able to import video in the same manner as described above, or by simply copying and pasting, using Window's Clipboard. Until that time, the following method allows video clips to be shown within Adept, by halting the Adept program, and invoking the Windows Media Player. Chapter IV outlined some dangers of using this method, however it is the only way to include video until an OLE-compliant version of Adept is released.

To build video into Adept screens, the user must first go to the area of the program where the video is desired. Next, the user must select a "Custom Node." Once this node is selected, the user should double-click on the new node. Now, the user is presented with the option to "Edit Script." The user should choose this option, and in the dialog box that appears, type in the following, case-sensitive script:

RunProgram("c:\\windows\\mplayer.exe c:\\adept\\video.avi",1).

The RunProgram portion of the script is Adept's function that enables other Window's programs to be used during Adept sessions. The next part of the script gives the location of the Windows Media Player, and must be followed verbatim. If the Media Player is in

102

a different directory, that directory should replace "windows." The space following the call for the Media Player is required. The next section points to the directory where the specific video file is located. In this case, the video file is named "video.avi." The user should substitute this with the appropriate file-name. The particular video file must be located in the Adept directory or Adept path for this function to operate properly. Finally, the comma after the closed quotes followed by the number one tells Adept to bring up the video in its maximum size.

Once these script procedures have been conducted, the custom node must be linked to the appropriate display node. Some method of invoking the video, i.e., via a button, should be constructed using normal Adept procedures. To test the script, the user must enter the "Run" mode. When the proper display screen with the button linked to the custom node appears, the user should click on the button. If a video display window appears, with Windows Media Player directly below it, the script executed properly. The user can position the video display window and Media Player into the desired position on the screen by dragging it with the mouse or pointing device. To play the video clip, the user should click on the play button located on the face of the Media Player. To close the video, the user must double-click on the upper-left corner of the Media Player (Warning, if the end-user of the Adept application accidentally moves the video display window, or Media Player from its original location, the next time it is invoked, it will appear in the new position). If the video does not appear, or an error message is received, the user should return to the Procedure Builder mode and check to see that the script was entered

103

properly, or that the proper locations of the Media Player, or video file were defined. Refer to the Adept "Help" option for additional instructions for using the "RunProgram" option.

C.   INSTRUCTIONS FOR EMPLOYING SOUND IN THE MAES

To incorporate sound in an Adept application, follow the exact same instructions for importing video, but instead, substitute the name of the sound file in place of the video file name in the Adept script. For instance, a script for the sound would appear as:

RunProgram("c:\\windows\\mplayer.exe c:\\adept\\sound.wav", 1).

Here, the only change in the script appears in the file name. It indicates a Windows "Wave Audio" file called "sound.wav" that contains the desired sound. Again, the sound file must be located in the Adept directory for the sound to play properly. To test the script, enter the "Run" mode and execute the button that is linked to this sound file. Instead of a video view window appearing, only the Windows Media Player will appear. The sound is then played, by depressing the Media Player's "Play" button. After playing the sound file, the end-user must double-click on the upper-left corner of the Media Player to close the file. The dangers associated with leaving instances of the Media Player running in the background were described in Chapter IV.

APPENDIX C. RECOMMENDATIONS FOR PURCHASING PORTABLE COMPUTERS FOR HOSTING MULTIMEDIA APPLICATIONS

This appendix provides the hardware and software recommendations to be taken into consideration when purchasing IBM-compatible portable computers intended to support multimedia applications. There are separate sections and recommendations for portables that will host graphics only, graphics and video only, or graphics, video, and sound. This appendix does not provide brand-name recommendations, merely specifications. These recommendations are not the minimum hardware requirements, but the author's personal views gained during the research for this thesis. Additionally, these recommendations maintain the greatest degree of mobility for the portable PC. The minimum requirements are provided in Chapter II, Table 1, the MPC2 specifications.

A. RECOMMENDED HARDWARE/SOFTWARE FOR GRAPHICS ONLY

As discussed in Chapter III, and in the previous paragraph, the following recommendations should ensure the best possible display of high-resolution graphic images on a portable computer:

Processor:	486-25 MHz or faster, SLC or built-in power management preferred
RAM:	8 Megabytes
Display Screen:	Capable of 256 shades of gray (color preferred), Active or Passive Matrix. Must be capable of attaching external VGA monitor

Graphics Display Card:	512 kilobytes onboard memory (permits 256 shades of gray or 256 colors)
Hard-disk drive:	120 megabytes or greater (larger permits more images)
Software:	Windows display driver permitting 256 shades of gray or color. Disk compression software to double logical size of hard-disk drive
Battery:	Extra battery to accommodate maximum up-time

B.   RECOMMENDED   HARDWARE/SOFTWARE   FOR   GRAPHICS   AND VIDEO

As discussed in Chapter IV, and in the previous section, the following recommendations should ensure the best possible display of high-resolution graphic images and video playback on a portable computer:

Processor:	486-50 MHz or faster, SLC or built-in power management preferred
RAM:	8 Megabytes
Display Screen:	Capable of 256 shades of gray (color preferred), Active or Passive Matrix. Must be capable of attaching external VGA monitor
Graphics Display Card:	512 kilobytes onboard memory (permits 256 shades of gray or 256 colors)
Hard-disk drive:	180 megabytes or greater (larger permits more images and video files) with access speed faster than 15 ms
Software:	Windows display driver permitting 256 shades of gray or color. Disk compression software to double logical size of hard-disk drive. Microsoft Video for Windows 1.0 Runtime software, with Media Player 2.0 supporting OLE.

106

Battery: Extra battery to accommodate maximum up-time

C.   RECOMMENDED HARDWARE/SOFTWARE FOR GRAPHICS, VIDEO, AND SOUND

As discussed in Chapter V, and in the previous sections, the following recommendations should ensure the best possible display of high-resolution graphic images, video playback, and sound playback on a portable computer:

Processor: 486-50 MHz or faster, SLC or built-in power management preferred

RAM: 8 Megabytes

Display Screen: Capable of 256 shades of gray (color preferred), Active or Passive Matrix. Must be capable of attaching external VGA monitor

Graphics Display Card: 512 kilobytes onboard memory (permits 256 shades of gray or 256 colors)

Sound Card: Internal sound card, 8-bit suffices, but due to new technology, only 16-bit may be available

Speakers: Built-in speaker with adjustable volume control

Hard-disk drive: 180 megabytes or greater (larger permits more images and video files) with access speed faster than 15 ms

Software: Windows display driver permitting 256 shades of gray or color. Disk compression software to double logical size of hard-disk drive. Microsoft Video for Windows 1.0 Runtime software, with Media Player 2.0 supporting OLE (supports digital audio as well). Windows audio device drivers for sound card

Battery: Extra battery to accommodate maximum up-time

LIST OF REFERENCES

1. Rosenborg, Victoria, *Technology Edge: A Guide to Multimedia,* New Riders Publishing, Carmel, Indiana, 1993.

2. Claiborne, David, "Now You See It!-It's Easier and Cheaper Than Ever to Add Full-motion Video to Windows Applications", *Windows Magazine,* October, 1993.

3. Rathbone, Andy, *Multimedia & CD-ROMs for Dummies,* IDG Books Worldwide, Inc., San Mateo, California, 1994.

4. Sprague, Ralph H., and McNurlin, Barbara C., *Information Systems Management In Practice, Third Edition,* Prentice Hall, Englewood Cliffs, New Jersey, 1993.

5. Jennings, Roger, *Discover Windows 3.1 Multimedia,* Que Corporation, Carmel, Indiana, 1992.

6. English, David, "Multimedia Spotlight: Media Vision Pro 16 Multimedia System II", *Compute,* via *America Online* Retrieval, December, 1993.

7. E, Jonathan, "Multimedia 101: Meeting of the Multimedia Minds", *MicroTimes,* Number 125, 25 July 1994.

8. *Indeo Video Release v3.2,* Intel Corporation, 27 June, 1994.

9. English, David, "How to Use Desktop Video", *Compute,* via *America Online* Retrieval, May, 1994.

10. *Intel Comparative Microprocessor Performance Index,* Intel Corporation, 1994.

11. *San Jose Mercury News, Computing,* Advertisement, 21 August, 1994.

12. *Hi-Tech USA,* Advertisement, *PC Computing,* August, 1993.

13. Hone, Robert, and Kuntz, Margy, *Making Movies with Your PC,* Prima Publishing, Rocklin, California, 1994.

14. *Intel Smart Video Recorder Installation Guide and Video Tips,* Intel Corporation, July, 1993.

15. Duberman, Dave, "Buyer's Guide to Digital Video Tools", *Morph's Outpost on the Digital Frontier,* Number 1-5, January 1994.

16. Worthington, Paul, "Product Spotlight: Hot New Multimedia Hardware", *Multimedia World,* August 1994.

17. Kahn, Ed, "What to Look for in a Laptop PC", *MicroTimes,* Number 123, 20 May 1994.

18. Stone, M. David, "Portable Multimedia: Taking Your Show on the Road", *PC Magazine,* Volume 13, Number 14, August, 1994.

19. Karnes, Clifton, "Cafe OLE", *Compute,* via *America Online* Retrieval, August, 1994.

20. McFarland, Tom, "Bitmapped Images and Diverse Palettes", *Morph's Outpost on the Digital Frontier,* Number 1-1, August 1993.

21. *Kodak Professional DCS 200 Digital Camera,* Brochure, Eastman Kodak Company, 1994.

22. Lauriston, Robert, "Portable Computing: A Balancing Act", *Windows Magazine,* via *America Online* Retrieval, April, 1994.

23. Rosenthal, Steve, "MPEG's Many Advantages: The VHS of Digital Video", *Multimedia World,* via *America Online* Retrieval, March, 1994.

24. *Microsoft Video for Windows User's Guide,* Microsoft Corporation, U.S.A., 1992.

25. Phone conversation with SoftSell's Adept Technical Support Line, June 14, 1994.

26. Lee, Yvonne L., "DTK's Pentium-based Notebook to Ship in June", *InfoWorld,* Volume 16, Issue 23, 6 June 1994. Page 34

27. *NCA Computer Products,* Advertisement, *MicroTimes,* Number 126, 24 August, 1994.

28. English, David, "Multimedia on the Road", *Compute,* via *America Online* Retrieval, August, 1994.

29. Meeting with MK 92 Engineers Mr. Doran Saurbier and Mr. Henry Seto, NSWC Port Hueneme, California, 21-22 June, 1994.

30. *PlayWrite 1000 Compact Disc Recordable System,* Advertisement, Microboards Corporation.

31. *Sony Multimedia CD Player,* Advertisement, Sony Corporation of America.

32. Fax to Mr. Doran Sauerbier, NSWC Port Hueneme, California, August 8. 1994.

33. *Adept User's Manual,* Symbologic Corporation, 1991.

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